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TRANSACTIONS

of the

American Society for Steel Treating

Vol. 1 Cleveland, June, 1921 No. 9

EXTENDING THE USE OF ALLOY STEELS

With the invention of the automobile and its continually growing importance in the industrial activity of the United States, the production of alloy steels has increased from a very low figure in 1908 to something over 2,000,000 tons in 1920. To be sure the automobile industry has not produced the only demand for alloy steel, but because of its rapid and uninterrupted growth, it has represented a goodly volume of the business. Peculiar requirements of the motor car, including ruggedness, resistance to shock, long serviceability and minimum weight, were responsible for the development and adaptation of this grade of steel for automotive parts. While straight carbon steel in various grades could be made to stand practically all of the physical requirements, the mass required to produce these qualities was so great that the assembled weight was excessive. Alloy steel offered similar physical properties but with considerable reduction in weight.

As illustrative of the rise of alloy steel, an article appearing elsewhere in this issue reviews the production of bessemer, open-hearth, crucible and electric steels for the last 54 years. A chart appearing with the article shows that within the 12 years the output of steel made by the last three methods has witnessed remarkable increase while bessemer production has remained at about the same level. Explanation of this lies in the fact that of the four processes of making steel, the bessemer alone does not adapt itself to the manufacture of alloy steel. Another chart with the same article shows the tremendous growth of the electric furnace method between 1908 and 1918. Open-hearth manufacture stands second in rate of growth, this process lending itself very readily to alloy steel production because of the simplicity of refining the metal in quantity.

Alloy steels are made containing different elements and different combinations of elements, each type having been so well standardized that it satisfies some definite requirement. Each type necessitates a definite heat treatment and to this fact, perhaps more than any other, is attributed the recent growth of the heat treating profession, for without careful and precise treatment the best of steel may be made worthless. The subject is too broad and too complex to discuss in detail but it may be said without reservation that alloy steel has come to stay and its application still is in its infancy. So far, its use is restricted largely to the automotive and high speed tool fields. However, its success there, coupled with a lower cost on a quality basis gives assurance that application will spread to other fields. It has been predicted and safely too that the time will come when alloy structural and fabricating steel will be used in considerable quantities for

buildings and bridges, for rails, locomotives, passenger and freight car parts, in boilers, wire rope construction and numerous other types of fabrication. This expansion predicts a greater field for steel treating.

PROFESSOR E. D. CAMPBELL ELECTED TO HONORARY MEMBERSHIP

At a meeting of the Board of Directors, on April 9, a petition was received from a large number of former students of Prof. E. D. Camp-

PROF. E. D. CAMPBELL

bell nominating him for honorary membership in the American Society for Steel Treating. The Board of Directors unanimously granted this petition in recognition of Professor Campbell's research work carried on in the laboratories of the University of Michigan, Ann Arbor, Mich., for the past 30 years.

Professor Campbell is director of the chemical laboratories at the university and his research work has dealt with the correlation of the chemical constituents to the physical properties of steel, considering mainly the theoretical aspect of the subject rather than the practical application of the ideas developed by the investigations.

Lt. Col. A. E. White, national president of the Society, presented Professor Campbell with his certificate of honorary membership at the meeting of the Detroit chapter held on May 21.

REPORT OF NOMINATING COMMITTEE, MAY 10, 1921

To the Secretary of the American Society for Steel Treating:

The National Nominating Committee, meeting according to the Constitution of the American Society for Steel Treating, selected as unanimous choice of those present the following men for nominees for office for the coming year.

President—F. P. Gilligan, Hartford, Conn.
1st Vice President—F. C. Lau, Chicago, Ill.
2nd Vice President—R. J. Allen, Springfield, Mass.
Treasurer—J. V. Emmons, Cleveland, Ohio.
Director—J. J. Crowe, Philadelphia, Pa.

According to Section 10 of Article VII of the By-Laws we are enclosing the written consent of these gentlemen to act.

Yours sincerely,
NATIONAL NOMINATING COMMITTEE,
American Society for Steel Treating.
(Signed) A. W. F. GREEN.
A. E. BELLIS.
C. U. SCOTT.
J. FLETCHER HARPER, Chairman.

REDUCED RATES TO INDIANAPOLIS

We are very glad to announce that the railroads of the country, through the Central Passenger Association, have granted fare and a half round trip for members of the Society and their dependents, for the Indianapolis Convention and Exhibition, Sept. 19 to 24. A large number of members and guests are always in attendance at this Convention, thus the railroads unanimously decided to recognize the Society to the extent of granting the fare and a half for the round trip.

There are certain restrictions placed on the purchase of these tickets inasmuch as an identification certificate must be presented to the ticket agent for the purchase of the round trip ticket. This identification certificate will be mailed to all the members of the Society before the first of September.

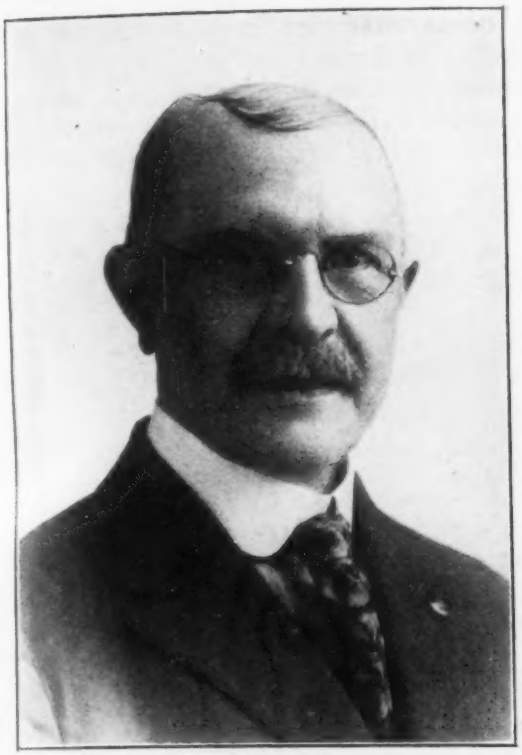
The reduction of railroad fares will contribute materially to an increase in attendance and there is no doubt but that the number visiting Indianapolis will be in excess of the 10,000 in attendance at Philadelphia.

HOTELS IN INDIANAPOLIS

Indianapolis has promised to provide our guests with excellent accommodations as far as hotels are concerned, and through the efforts of J. E. Burns Jr., chairman of the Hotel Committee, a list of hotels is given below.

All persons in attendance at Indianapolis will make their own reser-

FRANK P. GILLIGAN
Nominee for National President of the Society



F. C. LAU
Nominee for First Vice President of the Society

R. J. ALLEN
Nominee for Second Vice President of the Society

J. V. EMMONS
Nominee for National Treasurer of the Society

J. J. CROWE
Nominee for National Director of the Society

vations direct with the managers of the hotels, and it is advisable that the members take this precaution. When making reservations give date of arrival, kind of room desired, and price you wish to pay, and what is most important, request the hotel manager to answer your letter repeating the reservation. Then take the letter with you to present to the hotel clerk at Indianapolis when you register.

This precaution taken now may avoid serious difficulty at the time of the Convention.

It is recommended that reservations be made immediately.

The list of hotels follows:

Hotels	Capacity	Rates
Brevort Hotel	94 Rooms	$1.25 to $3.00 per day
New Colonial Hotel	92 "	$2.00 to $4.00 " "
New Denison Hotel	175 "	$1.25 to $2.00 " "
Edward Hotel	150 "	$1.25 to $4.00 " "
Grand Hotel	76 "	$1.50 to $3.00 " "
Hotel Lincoln	100 "	$6.00 " "
Lorraine Hotel	90 "	$1.00 to $4.50 " "
New Morton Hotel	65 "	$1.50 to $5.00 " "
Great Eastern Hotel	126 "	$1.25 to $3.00 " "
Stubbins Hotel	75 "	$1.00 to $4.50 " "
Hotel Severin	400 "	$2.50 to $8.00 " "
Hotel Washington	300 "	$5.00 to $8.00 " "
Hotel Williams	92 "	$1.75 up " "
Terminal Hotel	45 "	$1.50 up " "
Ohio Hotel	40 "	$1.50 up " "
Claypool Hotel	700 "	$2.50 up " "
Frohman Hotel	80 Rooms	Not over $3.50 per day
Haugh Hotel	60 "	" " " " " "
Linden Hotel	250 "	" " " " " "
Majestic Hotel	59 "	" " " " " "
Roosevelt Hotel	187 "	" " " " " "
Royal Hotel	85 "	" " " " " "

EXHIBITORS AT INDIANAPOLIS CONVENTION

The list of 40 firms given below have already contracted for space, and there are a number of other uncompleted contracts in the National office.

With the Convention still three months off, it is easily seen that this Exhibition is going to be one of the best ever held. The reason for the wonderful advance sale of space has been due primarily to the fact that the manufacturers realize this is a year in which they should stimulate trade, and also that it is a year in which their products will be sold upon their merits; and consequently they are anxious to present their products to the 10,000 visitors who will be in attendance at the Convention.

The advance sale is far in excess of the sale of space for the Philadelphia show last year.

A list of exhibitors who have contracted for space follows:

	Space No.
Charles Englehard, pyrometers and temperature control	4
George J. Hagen Co., electric and gas fired furnaces	8-9
Taylor Instrument Co., recording instruments	28
Brown Instrument Co., recording instruments	17
Quigley Furnace Specialties Co.	32

Hoskins Mfg. Co., electric furnaces and pyrometers 33
Eaton Electric Co., electric furnaces 20
Leeds & Northrup Co., electric furnaces and pyrometers 23-36
Bausch & Lomb Optical Co., metallographic equipment 24
William Ganschow Co., gears 37
Armstrong Cork & Insulation Co. 27
Spencer Turbine Co., air compressors 45
The Iron Trade Review, publications 58
Driver Harris Co., alloy pots and boxes 49
Crucible Steel Co. of America, steel 50-51-63
Halcomb Steel Co., steel 69-82
Bell & Gossett Co, case hardening materials 74
Case Hardening Service Co., carburizing materials 87
The Iron Age, publications 75
General Alloys Co., "Q" Alloys 94-107
Colonial Steel Co., steel 108
Electric Alloy Steel Corp., steel 100
E. C. Atkins Mfg. Co., saws and cutting off machines 154-153
Herman A. Holz, metallographic equipment ..... Unassigned
Bureau of Standards research work 123-124
Deeds & Chapin, Cinch Cement 81
Bethlehem Steel Co., steel 44-57
Marschke Mfg. Co., grinders and buffers 31
Indianapolis Drop Forging Co., forgings 19
Simonds Mfg. Co., steel and steel products 34
Heppenstall Forge & Knife Co., forgings, die blocks 126
Tate-Jones Inc., furnaces 25
Witherow Steel Co., steel 62
Midvale Steel Co., steel 18
Selas Co. 3
Smith Gas Engineering Co., gas producers 7
Vanadium Alloys Steel Co., steels 125
General Electric Co., electrical equipment 35
Westinghouse Electric Mfg. Co., electrical equipment ..... A & B
Ludlum Steel Co., steel 30-43
Bristol Co., pyrometers 40

LETTERS TO THE EDITOR

May 19, 1921.

Editor Transactions:

I believe I have an appreciable, though not overwhelming sense of modesty, and it received a rude jolt when I read the last paragraph of the story of the Philadelphia Membership Campaign, appearing in the May TRANSACTIONS, and of which I was credited with being the author. Please let me say that I did not write this paragraph and that it was added without my knowledge, apparently by some kind friend. I certainly do not wish to claim, and will not accept, any special credit for the success of the campaign. We all worked together. I believe that all results were largely in proportion to enthusiasm for the cause.

(Signed) H. C. Knerr
Philadelphia Chapter

The above portion of a letter is self-explanatory. The statement to which Mr. Knerr objects was not written by Mr. Knerr and through fault of the editor was allowed to appear improperly under his signature.

STEEL PRODUCTION IN UNITED STATES
1 FOR BESSEMER • 1867
1 FOR OPEN HEARTH • 1869
1 FOR ELECTRIC • 1908
CHART SHOWS FIRST ELEVEN (11) YEARS OF PRODUCTION OF EACH GRADE
BESSEMER STEEL
ELECTRIC STEEL
OPEN HEARTH STEEL
YEARS
THOUSANDS OF TONS

STEEL PRODUCTION IN THE UNITED STATES 1864 - 1918
BESSEMER
OPEN HEARTH
CRUCIBLE
ELECTRIC FURNACE
VERTICAL VALUES IN COMBINATION OF COMMON COORDINATE AND LOGARITHMIC SCALES
YEARS
MILLIONS OF TONS (2240 LBS PER TON)

Fig. 1—Steel Production in the United States, 1864-1918. Fig. 2—First 11 Years of Production of Various Grades of Steel

ALLOY STEEL—ITS RISE AND SECRETS

By Lieut. Col. A. E. White*

(A Paper Presented Before Several Eastern Chapters)

Turning to the Encyclopaedia Britannica we find the following: "Iron, the most abundant and the cheapest of the heavy metals, the strongest and most magnetic of known substances, is perhaps also the most indispensable of all save the air we breathe and the water we drink. For one kind of meat we could substitute another; wool could be replaced by cotton, silk or fur; were our common silicate glass gone, we could probably perfect and cheapen some other of the transparent solids; but even if the earth could be made to yield any substitute for the forty or fifty million tons of iron which we use each year for rails, wire, machinery, and structural purposes of many kinds, we could not replace either the steel of our cutting tools or the iron of our magnets, the basis of all commercial electricity. This usefulness iron owes in part, indeed, to its abundance, through which it has led us in the last few thousands of years to adapt our ways to its; but still in chief part first to the single qualities in which it excels, such as its strength, its magnetism, and the property which it alone has of being made at will extremely hard by sudden cooling and soft and extremely pliable by slow cooling; second, to the special combinations of useful properties in which it excels, such as its strength with its ready welding and shaping both hot and cold; and third, to the great variety of its properties. It is a very Proteus. It is extremely hard in

*Director, department of engineering research, University of Michigan, Ann Arbor, Mich., and national president American Society for Steel Treating.

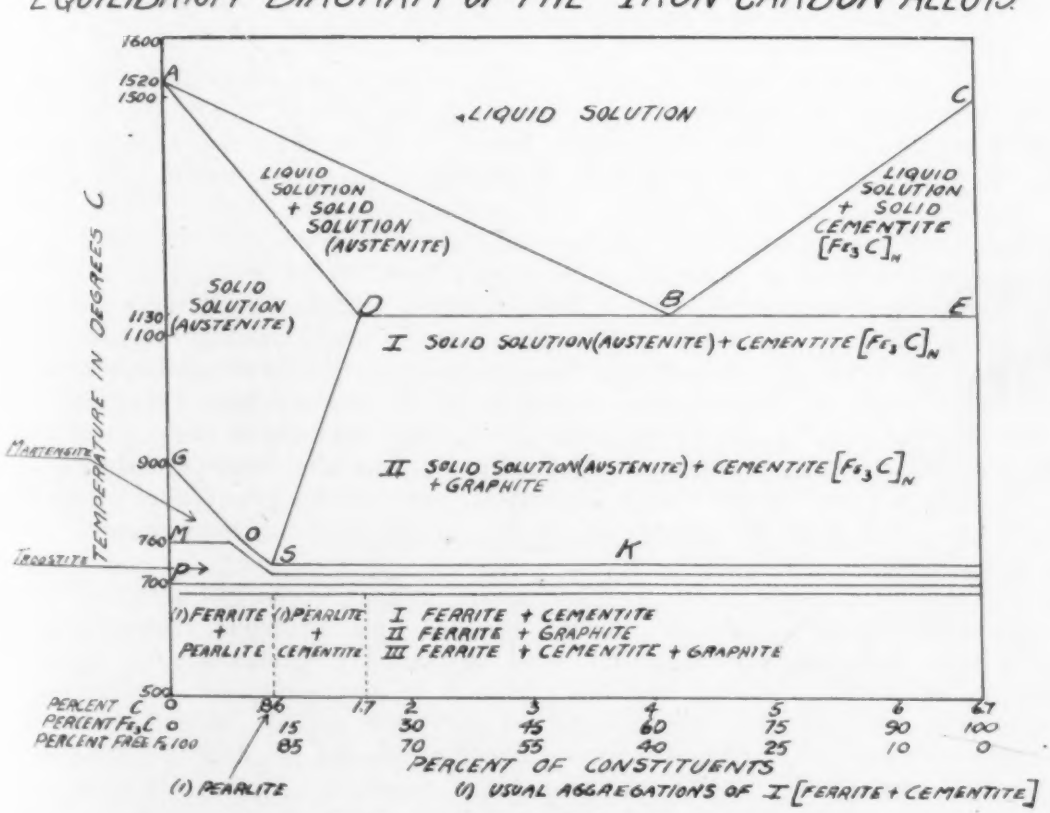


Fig. 3—Equilibrium Diagram of the Iron-Carbon Alloys

Table I

MENDELEEFF'S PERIODIC TABLE

Series	Group O	Group I RH R_2O	Group II RH_2 RO	Group III RH_3 R_2O_3	GroupIV RH_4 RO_2
1	....	H = 1.008	....	....	....
2	He = 3.99	Li = 6.94	*Gl = 9.1	B = 11.0	C = 12.0
3	Ne = 20.2	Na = 23.0	Mg = 24.32	Al = 27.1	Si = 28.3
4	A = 39.88	K = 39.1	Ca = 40.07	Sc = 44.1	Ti = 48.1
5	....	Cu = 63.57	Zn = 65.37	Ga = 69.9	Ge = 72.5
6	Kr = 82.92	Rb = 85.45	Sr = 87.63	Yt = 89.0	Zr = 90.6
7	....	Ag = 107.88	Cd = 112.40	In = 114.8	Sn = 119.0
8	X = 130.2	Cs = 132.81	Ba = 137.37	La = 139.0	Ce = 140.25
9	....	....	....	Er = 167.7	....
10	....	....	....	....	....
11	....	Au = 197.2	Hg = 200.6	Tl = 204.0	Pb = 207.1
12	....	....	Ra = 226.4	....	Th = 232.4

Elements not placed in above table are Tb = 159.2, Dy = 162.5, Tm = 168.5, Lu = 174.0, Nt = 222.4 = Niton = Emanium = radium emanation

our files and razors, and extremely soft in our horse-shoe nails, which in some countries the smith rejects unless he can bend them on his forehead; with iron we cut and shape iron. It is extremely magnetic and almost nonmagnetic; as brittle as glass and almost as pliable and ductile as copper; extremely springy, and springless and dead; wonderfully strong, and very weak; conducting heat and electricity easily, and again offering great resistance to their passage; here welding readily, there incapable of welding; here very infusible, there melting with relative ease. The coincidence that so indispensable a thing should also be so abundant, that an iron-needing man should be set on an iron-cored globe, certainly suggests design. The indispensableness of such abundant things as air, water and light is readily explained by saying that their very abundance has evolved a creature dependent on them. But the indispensable qualities of iron did not shape man's evolution, because its great usefulness did not arise until historic times, or even, as in case of magnetism, until modern times.

"These variations in the properties of iron are brought about in part by corresponding variations in mechanical and thermal treatment, by which it is influenced profoundly, and in part by variations in the proportions of certain foreign elements which it contains; for, unlike most of the other metals, it is never used in the pure state. Indeed pure iron is a rare curiosity. Foremost among these elements is carbon, which iron inevitably absorbs from the fuel used in extracting it from its ores. So strong is the effect of carbon that the use to which the metal is put, and

Table I

MENDELEEFF'S PERIODIC TABLE

Series	Group V RH_3 R_2O_5	Group VI RH_2 RO_3	Group VII RH R_2O_7	Group VIII RO_4
1	....	....	....	....
2	N = 14.01	O = 16.0	F = 19.0	....
3	P = 31.04	S = 32.07	Cl = 35.46	....
4	V = 51.0	Cr = 52.0	Mn = 54.93	Fe = 55.84 Ni = 58.68 Co = 58.97
5	As = 74.96	Se = 79.2	Br = 79.92	....
6	*Nb = 93.5	Mo = 96.0	....	Ru = 101.7 Rh = 102.9 Pd = 106.7
7	Sb = 120.2	Te = 127.5	I = 126.92	....
8	Pr = 140.6	Nd = 144.3	....	Sa = 150.4 Eu = 152.0 Gd = 157.3
9	Yb = 172.0	....	....	....
10	Ta = 181.5	W = 184.0	....	Os = 190.9 Ir = 193.1 Pt = 195.2
11	Bi = 208.0	....	....	....
12	....	U = 238.5	....	....

*Gl = Glucinum = Be = Beryllium
Nb = Niobium = Cb = Columbium

indeed its division into its two great classes, the malleable one, comprising steel and wrought iron, with less than 2.20 per cent of carbon, and the unmalleable one, cast iron, with more than this quantity, are based on carbon content."

Of significance in addition to the carbon are the special elements; nickel, chromium, vanadium, molybdenum, tungsten and silicon and manganese in percentages above those found in straight carbon steels.

However else we may characterize this present age we can, without any hesitancy, speak of it as the "Age of Steel." Beginning in the early sixties of the last century, at just about the time that the Civil War broke out, the first glimmerings of the present age appeared. Up to that time the only steel made was either in the cementation or crucible processes.

The increase in the production of steel in this age is indicated by the comparisons of the tonnages of steel produced in 1864 and 1918. In the former year 13,627 tons were made and in the latter year a tonnage 3260 times as great or, to be exact, 44,462,432 tons.

This growth in the consumption of steel products is shown in Fig. 1. The tonnages of bessemer, open hearth, crucible, and electric furnace steels are given from the year 1867 for bessemer, 1869 for open hearth, 1872 for crucible, and 1908 for electric furnace, to and through the year 1918. The year 1867 was selected for the bessemer, 1869 for the open hearth and 1908 for the electric furnace grades since these were the first

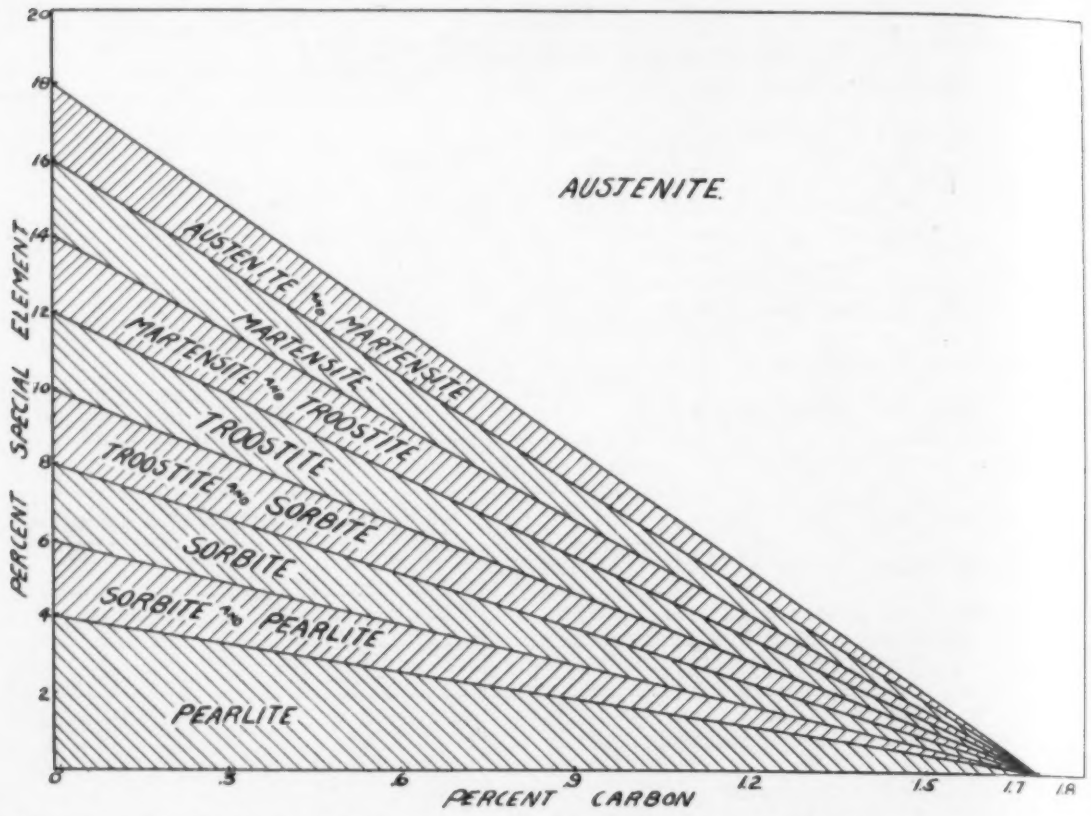


Fig. 4—General Constitutional Diagram for Special Steel in Which Special Element Tends to Hold the Carbon in Solution

years of which there is any record of the production of any appreciable tonnage of steel of these various types. The year 1872 was selected for the crucible steels since this was the first year of a separate notation for this grade. Attention is particularly called to the very rapid increase in the production of steel which has taken place in this country, and which has resulted in placing this land in a leading position in this field of activity.

For the sake of drawing attention to the remarkable rise of electric furnace steel there is shown in Fig. 2 the growth of bessemer, open hearth and electric furnace steels during their first 11 years of production. The chart demonstrates the phenomenal growth of bessemer steel, the equally phenomenal growth of electric furnace steel and the more conservative growth of open hearth steel. To be sure the production of bessemer steel is no longer on the increase owing to the acknowledged superior qualities, for most purposes, of open hearth and electric furnace steels and the impetus which improved methods of handling and other operating details have given to open hearth steels particularly, enabling them, thereby, to compete on a cost basis with bessemer steels.

It is with regret that no figures for alloy steels are given. There seems to be little data available on this point. It has been stated that there was produced during the past year about 2,000,000 tons of alloy steel. If this is the case then we would not be far from the facts if we assumed that four times the tonnage of electric furnace steel represented the tonnage of alloy steel. To be sure small quantities of alloy steel were made previous to 1908. Nickel steel has been particularly well

known for the past 25 years, although in its early days it was used almost exclusively in steel for armament purposes. Alloy steel for structural and fabricating purposes, types with which this paper is chiefly concerned only began to come into its own with the advent of the automobile. With the growth of this industry there has been a corresponding growth in the consumption of alloy steel. It is believed to be a fair prediction, though, that the day is about to break when alloy structural and fabricating steel will be used in considerable quantities in structural work, bridges and buildings, in the field of transportation for rails and for locomotives, passenger and freight car parts, in boilers, wire rope construction and numerous other types of fabrication.

The various grades of steel that will be touched upon in this article are plain carbon steels and structural and fabricating alloy steels. The term "structural and fabricating" is used as an antithesis to high speed steels for there will be no attempt to discuss at this time this latter class of steel. Of the alloy steels, discussion will center around nickel, chromium, manganese, silicon, nickel-chromium, chrome-molybdenum and chrome-vanadium.

On the part of many individuals there has been an attempt to classify these steels with a view to correlating their respective properties and enabling a prediction of properties that might be expected from other elements should they be used.

Osmond arranged a number of the elements in the order of their atomic volumes, and found by dividing their atomic weight by their specific gravity:

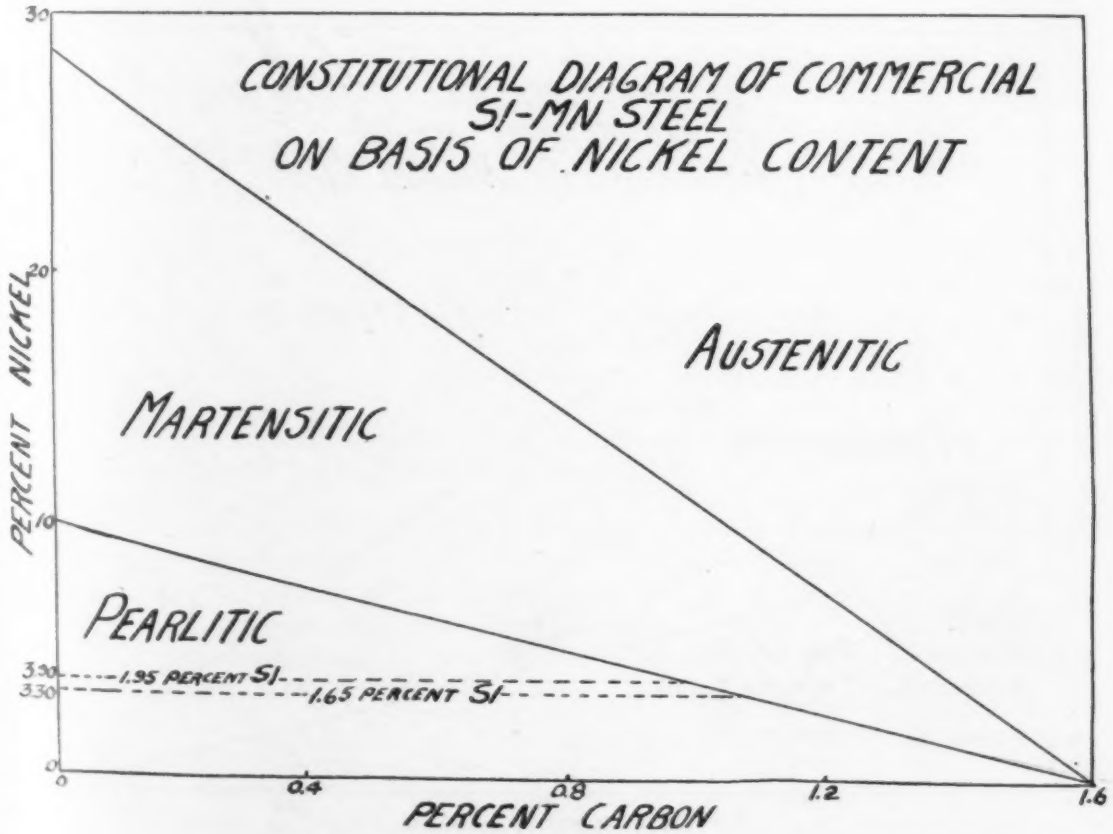


Fig. 5—Constitutional Diagram for Nickel Steels —*Sauveur*

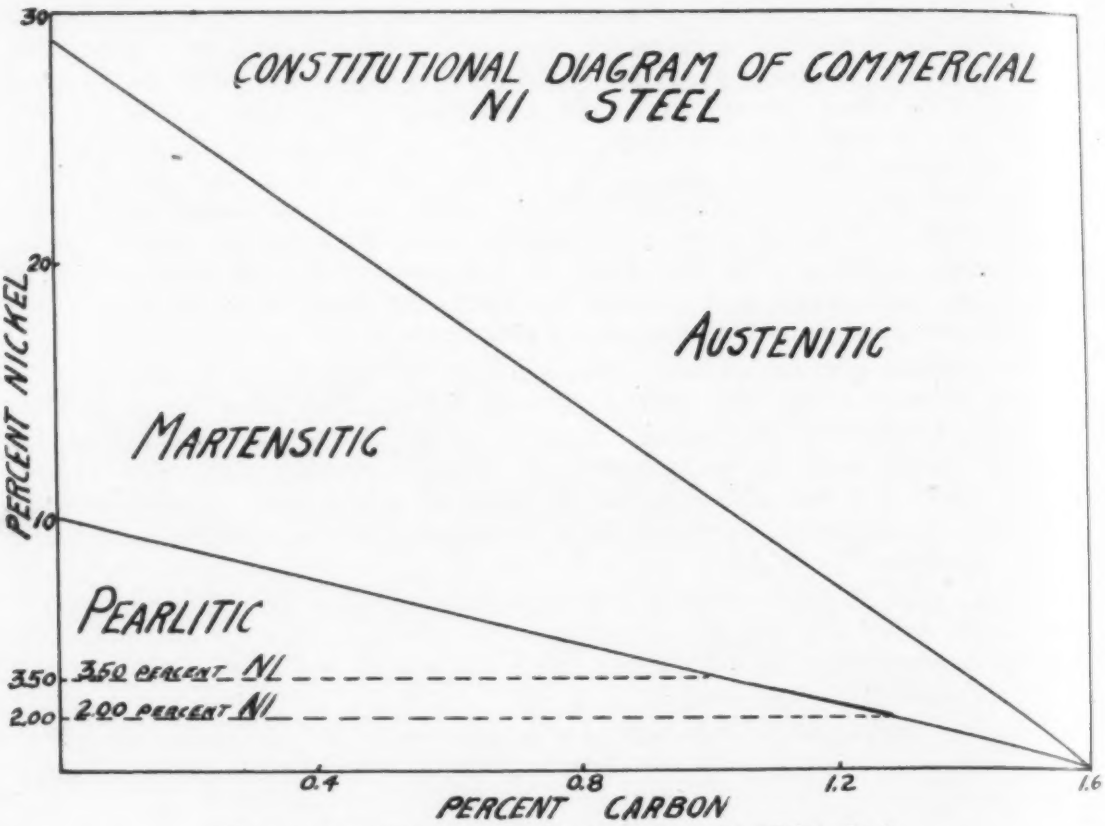


Fig. 6—Constitutional Diagram for Commercial Nickel Steels

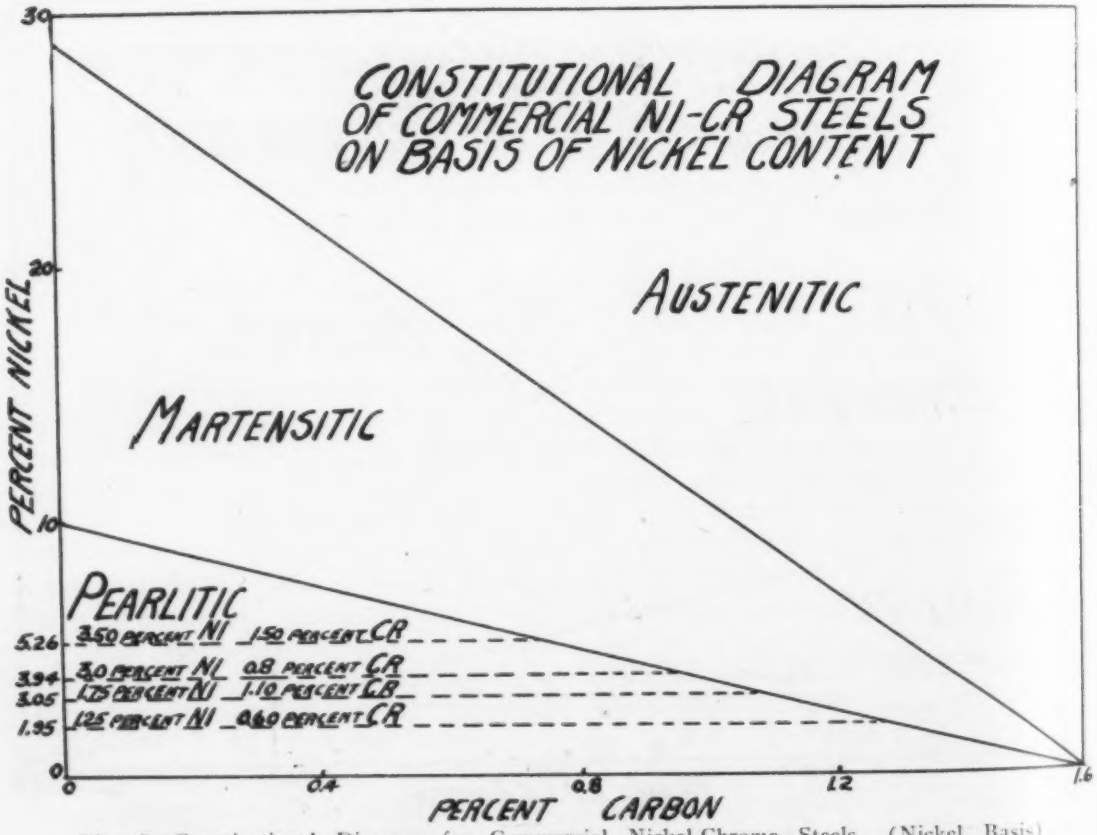


Fig. 7—Constitutional Diagram for Commercial Nickel-Chrome Steels. (Nickel Basis)

I.		II.	
Carbon	3.6	Chromium	7.7
Boron	4.1	Tungsten	9.6
Nickel	6.7	Silicon	11.2
Manganese	6.9	Arsenic	13.2
Copper	7.1	Phosphorus	13.5
		Sulphur	13.7

Elements According to Atomic Volumes.

He considered that the elements in Column I, whose atomic volumes are smaller than that of iron (7.2), delay the Ar_3, Ar_2, and Ar_1 transformations, while elements whose atomic volumes are greater than that of iron (Column II) tend to raise the temperature at which those changes occur. There can be no doubt that this arrangement is quite inadequate, because the action of the above elements cannot be arranged in two simple columns, and also because it does not take into account the fact that they may form new compounds with the carbon and the iron.

Also there have been those who have made attempts to show the relation between the position of the elements in Mendeleeff's periodic table and their effect upon the properties of iron and steel. For instance, in Group VI of Table 1 there is chromium, molybdenum and tungsten. All of these elements impart to steel certain properties which are closely analogous. It is assumed, by some, therefore, that uranium which is in the same group will impart similar properties. Within certain limits this is doubtless true. In Group IV there is silicon, titanium and zirconium. These elements have within certain limits similar deoxidizing effects on steel. Will the remaining elements in this group have similar effects? Edwards answers this question in some measure when he says:

"Nevertheless, it is more than probable that the chemical and physical action of the various elements upon iron and steel is in some way governed by their atomic or molecular constitution, and, if this be so, we may reasonably hope that some useful theory or law similar to the periodic classification of the elements will ultimately be discovered. Before this can be satisfactorily accomplished, however, the various chemical compounds which the elements are capable of forming, both with the iron and carbon, must be carefully isolated."

The open door to the secrets of alloy steel is through constitutional diagrams. The parent of all of these is the iron carbon alloy diagram given in Fig. 3. Without minutely studying this diagram we know that when steel is brought up to a temperature which, when taken in connection with its composition is the zone *ADSOG* austenite is formed, when in the zone *GOM* martensite is formed, and when in the zone *MOS* troostite is formed. Also the constituents of annealed steel in the zone below line *PS* and to the left of point *S* are ferrite and pearlite, or ferrite and sorbite, when below line *SK* but to the right of point *S* the constituents are pearlite and cementite or sorbite and cementite, and if directly at or below *S* the constituent is either pearlite or sorbite. The

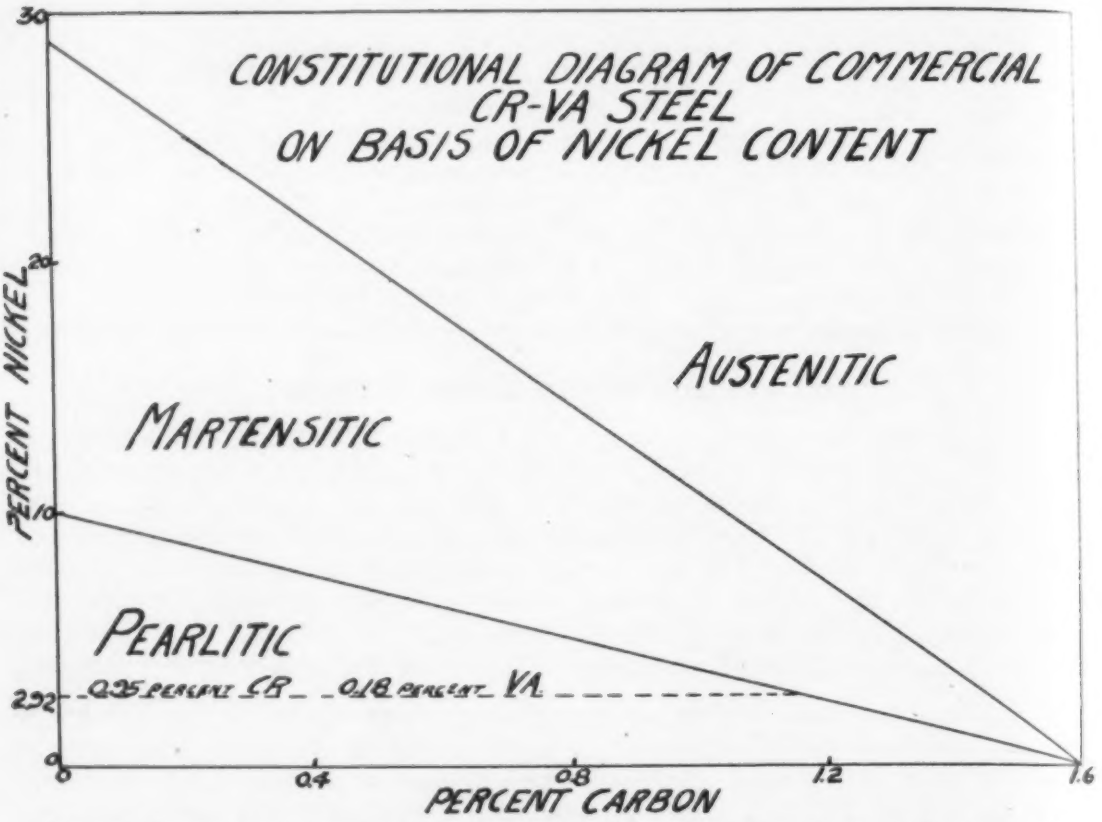


Fig. 8—Constitutional Diagram for Commercial Chrome-Vanadium Steels. (Nickel Basis)

diagram also shows by the line parallel to *OS* and the lines parallel to *PSK* that the zones just mentioned for martensite and troostite are not the only ones in which it is possible for martensite and troostite to occur. Briefly, the constitution of these constituents is as follows:

Ferrite is pure iron. All of the area given in Fig. 20, except the very blackest is ferrite. Cementite is carbide of iron containing 6.67 per cent carbon with the formula Fe_3C. It is shown in Fig. 21 as the white.

Pearlite, shown in Fig. 22, is a mechanical mixture of ferrite and cementite containing approximately 88 parts of ferrite and 12 parts of cementite with a total carbon content of 0.86 per cent. From the laminated nature of its makeup it derives its name. The black is the ferrite, the white the cementite, the two together forming the pearlite. Sorbite is essentially the same as pearlite but for the nature of the mixture of the cementite and the ferrite. These two constituents do not manifest a laminated appearance. Its appearance is given in Fig. 23. The black areas are sorbite.

Austenite is a solid solution of carbon or carbide of iron in gamma iron. Martensite and troostite are presumably transition forms between austenite on the one hand and ferrite and cementite on the other. Both martensite and troostite probably contain all three of the constituents just named—austentite, ferrite, and cementite—though in varying proportions for both the respective constituents and in each respective constituent. In Fig. 24 is shown both austenite—white—and martensite—dark and needlelike—and in Fig. 25 is both martensite—white—and troostite—dark.

This is not a good illustration of austenite and martensite. In fact

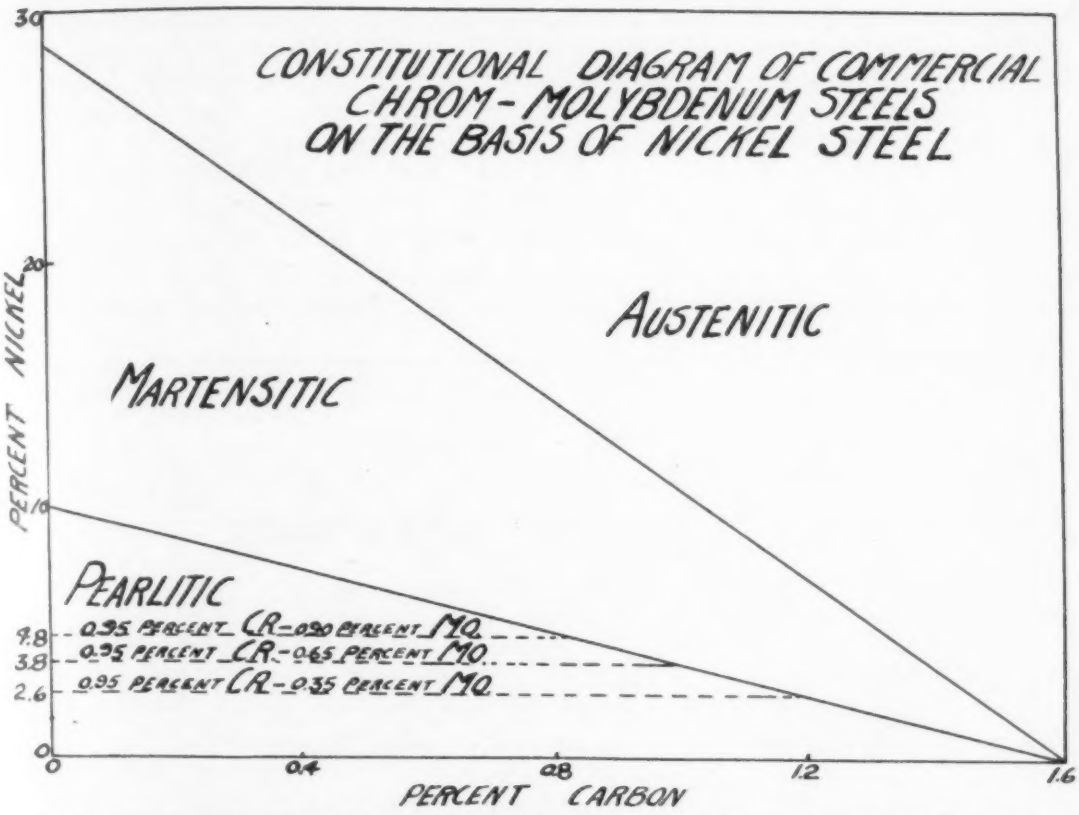


Fig. 9—Constitutional Diagram or Commercial Chrome-Molybdenum Steels. (Nickel Basis)

I doubt whether any martensite is present. The dark needles look more like slip bands or X-bands.

In alloy steels these are no more nor no less constituents than in plain carbon steels. The addition of the special element or elements rendering them special steels, however, accentuates the ease with which given desired constituents may be produced. Realizing that each of the constituents has particular properties of its own, the question of the production of special properties resolves itself into procuring given constituents of a given degree of saturation. It has been so customary to think of special steels in terms of composition and heat treatment that the desirability of at times speaking of a steel in terms of constituents has sometimes been overlooked.

Special elements probably act in one of three ways. Either they tend to keep the carbon in solution, or tend to aid in throwing it out of solution as a single or compound carbide, usually the latter, or else they tend to keep the carbide in solution within certain limits and beyond these limits aid in throwing it out of solution. Most all structural and fabricating alloy steels belong to the first class and most high speed tool steels are of the last class.

In view of the narrowing down of the subject to structural and fabricating alloy steels most of the discussion will be directed only to this class of alloy steel and but little to the other remaining classes.

A general law for the effect of special elements which tend to keep the carbide in solution is stated in three parts as follows: (a) With a constant special element content, increases in the carbon content produce tendencies for the formation of austenitic steels. (b) With a constant

carbon content increases in the special element content produce tendencies for the formation of austenitic steel. (c) The transitions from pearlite to martensite to austenite are not distinct nor sharply defined.

These laws are set forth in Fig. 4. Thus with a steel containing X per cent of special element—a per cent so low that with 0.1 per cent carbon the steel would be in the pearlite zone—the steel would be known as pearlitic; that is, on air cooling from above its critical temperature pearlite would probably be produced. With a given increase in carbon sufficient for the intersection of the content of special element and carbon to occur in the martensite zone the steel would be martensitic; that

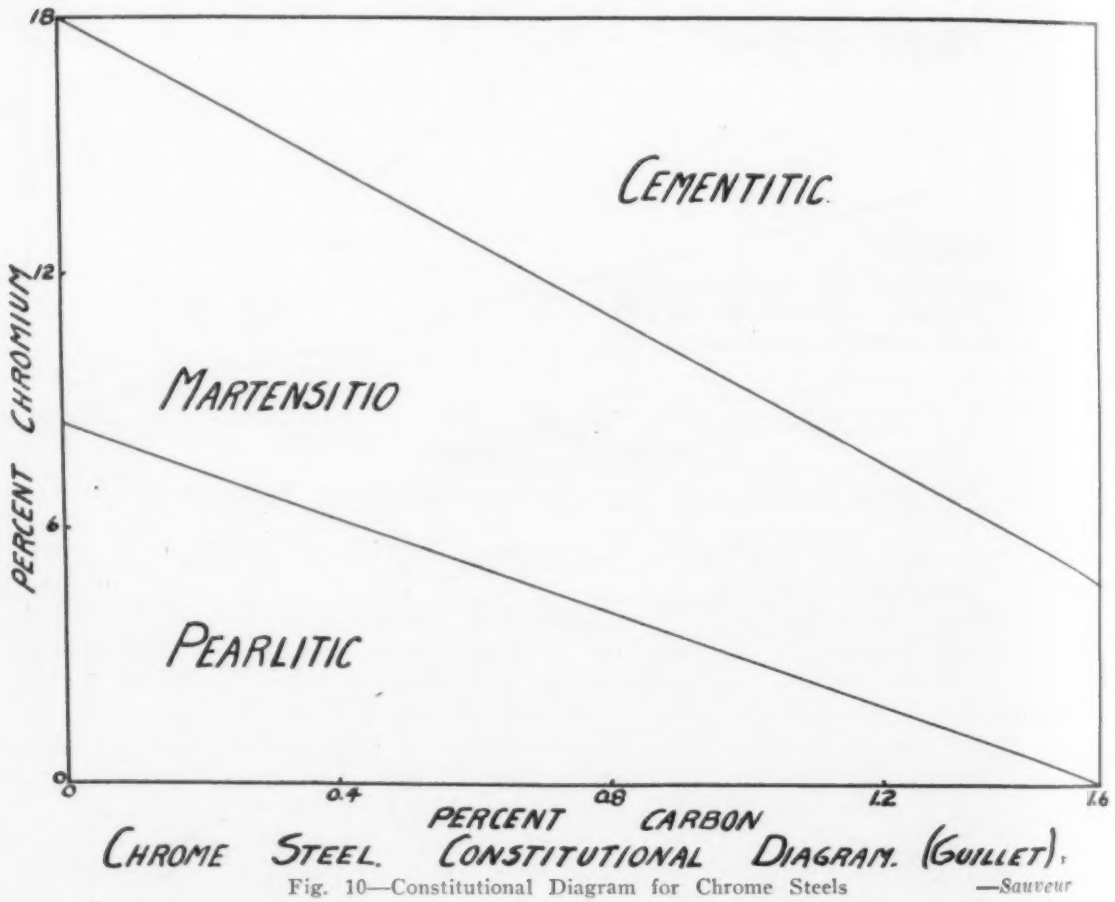


Fig. 10—Constitutional Diagram for Chrome Steels —*Sauveur*

is, on air cooling from above the critical temperature martensite would probably form. With increase in the carbon content to 1.7 per cent the steel would be austenitic; that is, on air cooling from above the critical temperature the constituent present would probably be austenite. In this same general manner it is not difficult to realize that by varying the percentages of carbon one can obtain on air cooling from above the critical temperature pearlite, transition forms between pearlite and martensite, martensite, transition forms between martensite and austenite, or austenite.

When looked at from the standpoint of a constant carbon content but a varying special element content, the same ability to get at will the constituent desired on air cooling from above the critical temperature is apparent. The only different set of conditions in this case over that last described is in the variation of the special element content in place of a

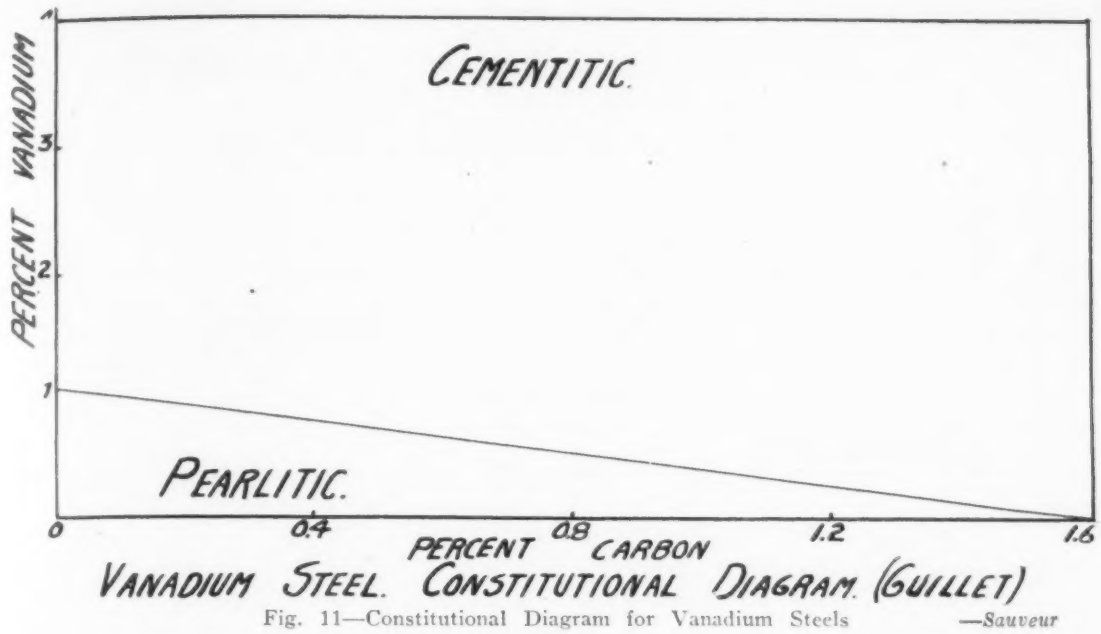


Fig. 11—Constitutional Diagram for Vanadium Steels —*Sauveur*

variation in the carbon content. It is further desired to point out that none of the constituent changes are sharp. Thus one constituent does not pass directly into another. Rather there is a gradual transition, a gradual passage.

The special elements of commercial importance are nickel, manganese, chromium, vanadium, molybdenum, tungsten and silicon. These may be added to steels individually to form ternary steels, in groups of twos to form quarternary steels, or even in groups of three, as is the case with a popular high speed steel, the special elements of which are tungsten, chromium, and vanadium, to form a quinternary steel.

Practically all of the structural and fabricating alloy steels are of

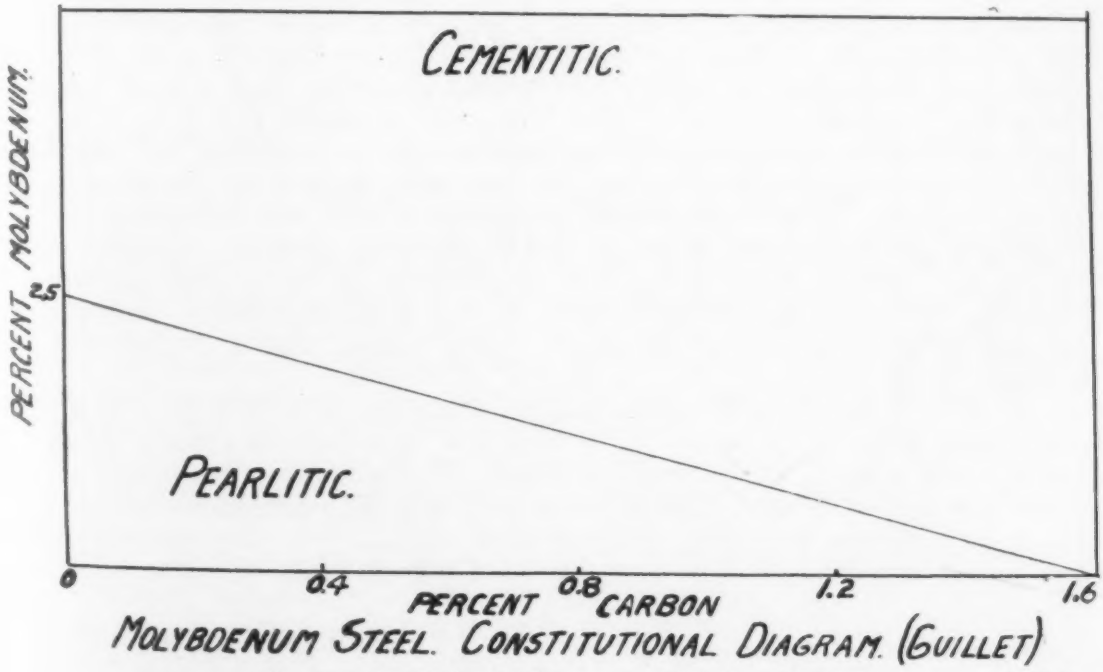


Fig. 12—Constitutional Diagram for Molybdenum Steels —*Guillet*

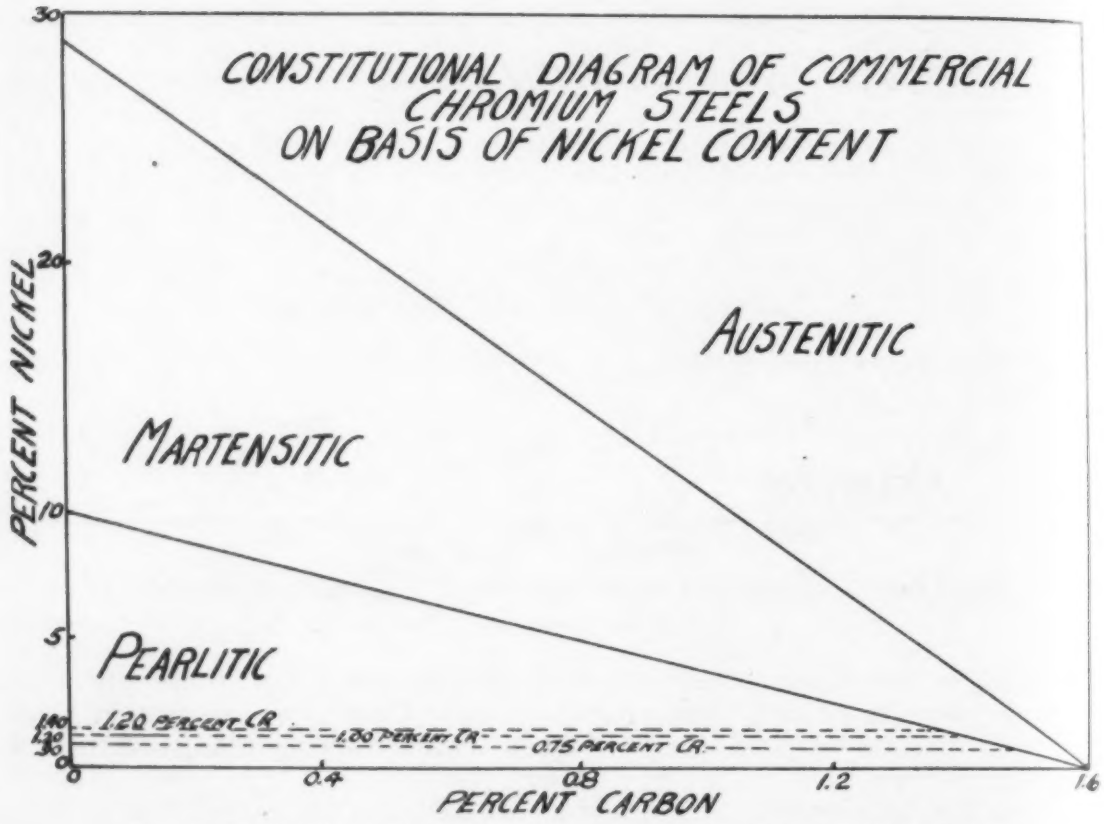


Fig. 13—Constitutional Diagram for Commercial Chrome Steels. (Nickel Basis)

the pearlitic type. That is, there is not enough of the special element or elements and carbon to place them out of the pearlitic zone. This means, therefore, that on slow cooling the carbon would be in the pearlite. To be sure rapid cooling would enable the production of sorbite, troostite, martensite or austenite, the constituent formed dependent upon the rate of the cooling; but this possibility would in no wise take them out of the pearlite class. Plain carbon steel can be so treated as to produce these same constituents, but no one would proclaim such a steel as anything but pearlitic.

Charts have been prepared for our common structural and fabricating steels, on the basis of nickel so that they might be viewed from a common plane. Practically speaking, there are but few structural or fabricating alloy steels with more than 0.45 per cent carbon. Most of these steels have such comparatively low percentages of the special element or elements that the type of steel would remain pearlitic with a carbon content of 0.80 per cent and in many cases, even, with a higher carbon content.

In Fig. 5 the straight constitutional diagram for nickel steel is given. Note that with but a trace of carbon the steel would remain pearlitic until 10 per cent of nickel were present. In Fig. 6 two grades of nickel steels are set into the regular constitutional diagram for nickel steel. These grades are the 2.0 per cent nickel and 3.5 per cent nickel steels. The nickel content is so low that for all of the amounts of carbon customarily used the steels remain pearlitic.

In Figs. 7, 8 and 9 are given some of the nickel-chrome (1.25 per cent nickel and 0.60 per cent chrome, 1.75 per cent nickel and 1.10 per

cent chrome, 3.00 per cent nickel and .80 per cent chrome, and 3.50 per cent nickel and 1.50 per cent chrome), chrome-vanadium (0.95 per cent chrome and 0.18 per cent vanadium), and chrome-molybdenum (0.95 per cent chrome and 0.35 per cent molybdenum, 0.95 per cent chrome and 0.65 per cent molybdenum, and 0.95 per cent chrome and .90 per cent molybdenum) steels.

The special elements in these steels are all converted to a nickel basis. Thus, since in nickel steels with only a trace of carbon 10 per cent of nickel would be required to take it out of the pearlitic class and since in chrome steels Fig. 10, 8 per cent of chrome would take this steel out of the pearlitic class chromium is assumed to be 10/8 or 1.25 times more powerful in this particular function than nickel. In the same way 1.0 per cent of vanadium, Fig. 11, may be said to compare with 10 per cent of nickel. Thus the conversion factor for vanadium is 10. In like manner

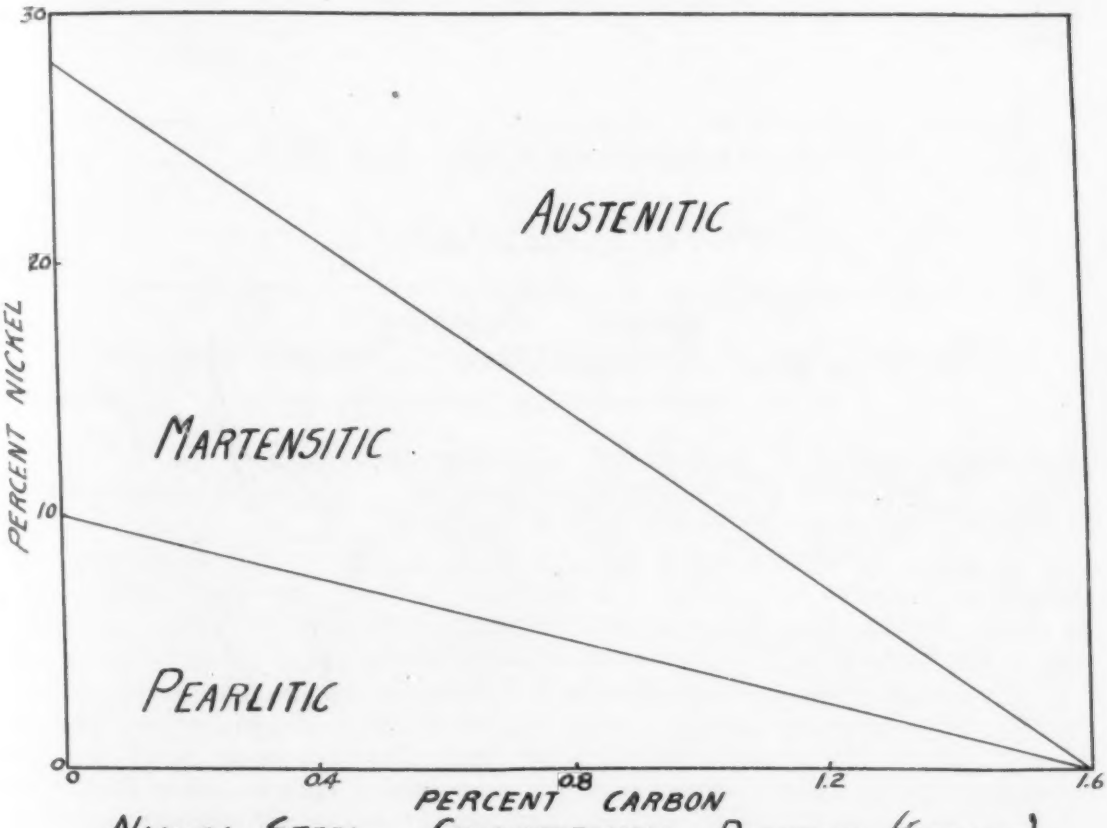


Fig. 14—Constitutional Diagram for Commercial Silicon-Manganese Steels. (Nickel Basis)

the conversion factor for molybdenum, Fig. 12, is 4. That is, from this particular view point 2.5 per cent of molybdenum may be assumed to be the equivalent of 10 per cent of nickel.

In Fig. 13 is given three of the commercial chrome steels (0.75 per cent chrome, 1.0 per cent chrome and 1.20 per cent chrome) converted into terms of nickel.

Fig. 14 gives two of the so-called silicon-manganese steels (1.65 per cent silicon and 0.70 per cent manganese, and 1.95 per cent silicon and 0.60 per cent manganese) converted to terms of nickel. The factor for silicon, Fig. 15 is 2. No account of the manganese has been taken for

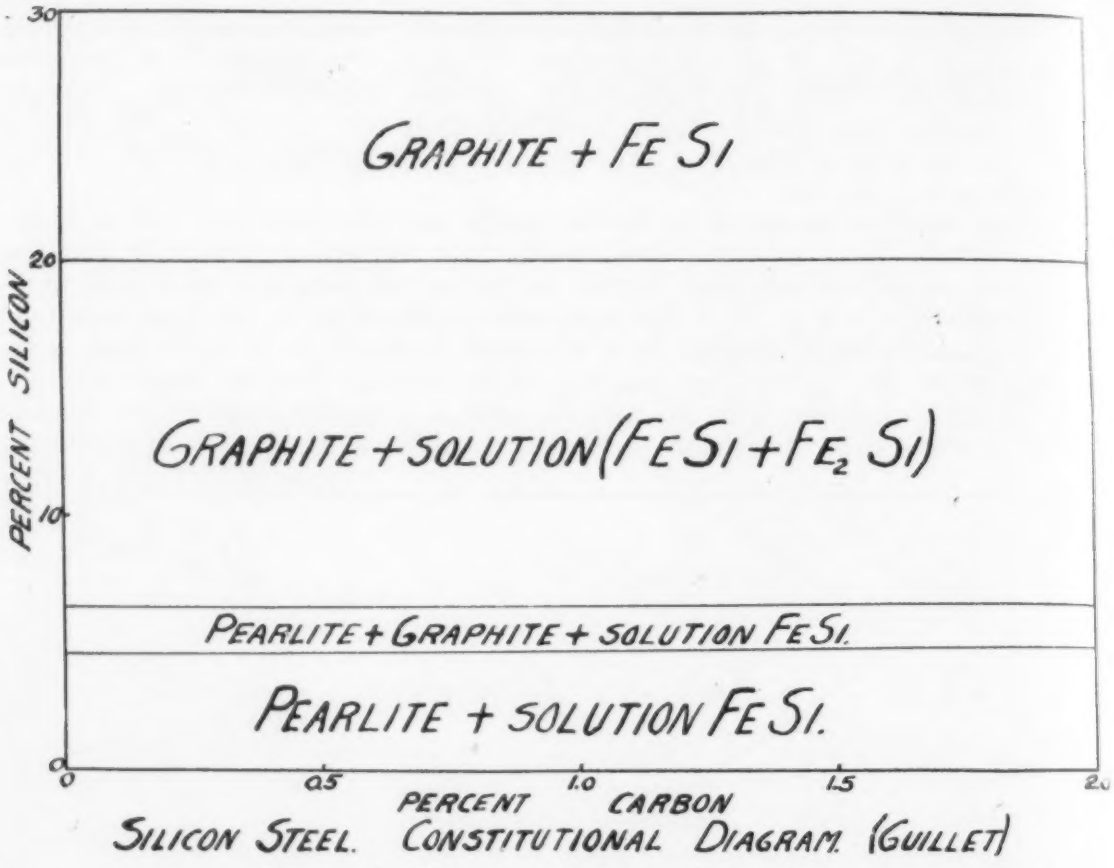


Fig. 15—Constitutional Diagram for Silicon Steels —*Sauveur*

it is not in quantities appreciably above those ordinarily found in alloy steels. Why these steels should be spoken of as silicon-manganese is not clear. They are essentially silicon steels.

A grade of steel known as magnet steel—essentially a chrome low tungsten product—converted into terms of nickel (See Figs. 10 and 16) is given in Fig. 17. The conversion factor for tungsten is 1. As previously mentioned the conversion factor for chromium is 1.25.

No claim is made that the heat treatment is the same for any of the alloy steels of the same carbon content with the same nickel equivalent content. Nor are conditions necessarily the same with respect to quenching mediums, time at heat, and other matters of a like character. The point which it is desired to emphasize is that all of the commercial structural and fabricating alloy steels are essentially of a type known as pearlitic; and the general laws—with proper variations to be sure—which apply to straight carbon steel with reference to heat treatment apply to these steels.

An alloy steel which seems to have excellent possibilities for rails but which has not been considered essentially a structural or fabricating steel is the manganese steel. It is usual for the manganese to be between 12 and 14 per cent. These amounts combined with the carbon make it an austenitic steel. As a steel it is so tough that it can be machined only with difficulty and therefore can find use only in parts not requiring that operation. Its constitution is given in Fig. 18.

In passing high speed tool steels should be touched upon. They are essentially composed of 18 per cent tungsten, 4 per cent chromium, and

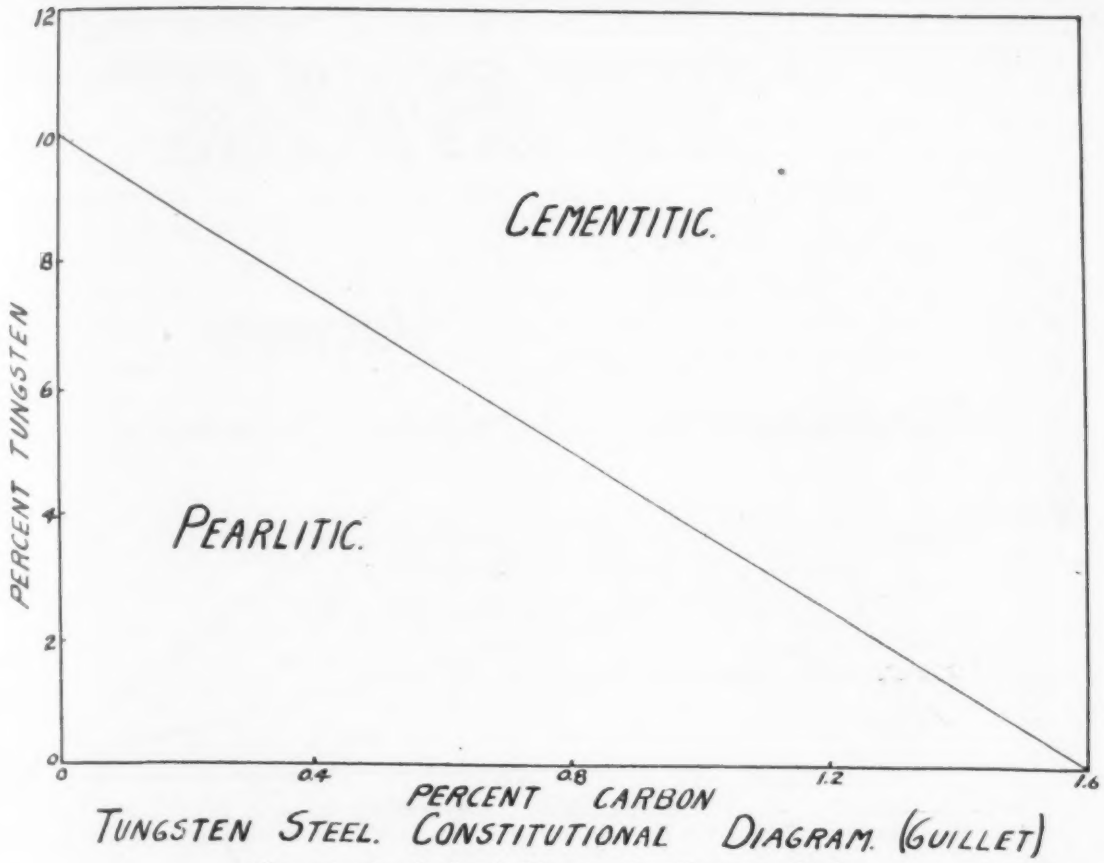


Fig. 16—Constitutional Diagram for Tungsten Steels —*Sauveur*

1.75 per cent vanadium. On the basis of tungsten, the chromium factor is 1.25 and the vanadium factor is 10. See Figs. 10 and 11. Thus a steel of the above composition, as shown in Fig. 19, has a tungsten equivalent of 38 per cent. This high percentage places it beyond all question in the cementitic class.

In the selection of any grade of steel there are numerous factors to be considered. Pre-eminent among these is cost. In the past there has been too much emphasis placed upon first cost and too little upon ultimate cost. Thus one grade of gear steel may cost 12 cents a pound and another grade 10 cents a pound. The lower priced steel may be selected and if used in a gear weighing 10 pounds, there may be an apparent saving of 20 cents per gear. Assume the cost of each gear up to inspection after heat treatment is $15.00, for the gear made of the lower priced steel and $15.20 for the gear made of the higher priced steel. Assume the scrap loss on the gear made of the lower priced steel is 5 per cent and on the gear made of higher priced steel is 2 per cent. Assume 200 gears are made per day. Under these conditions the cost of each acceptable gear made of the lower priced stock after heat treatment is $15.73, and of each gear made of the higher priced stock $15.49; a saving through the use of the higher priced stock of $48.00 per day or of $14,400 per 300-day year. Quality is not always a matter of price, though usually it is. The illustration is given not for the purpose of blindly proposing the use of high priced stock but for the purpose of pointing out that at times the higher priced stock may prove to be the cheaper.

Another vital factor is its cleanness, uniformity, and freedom from

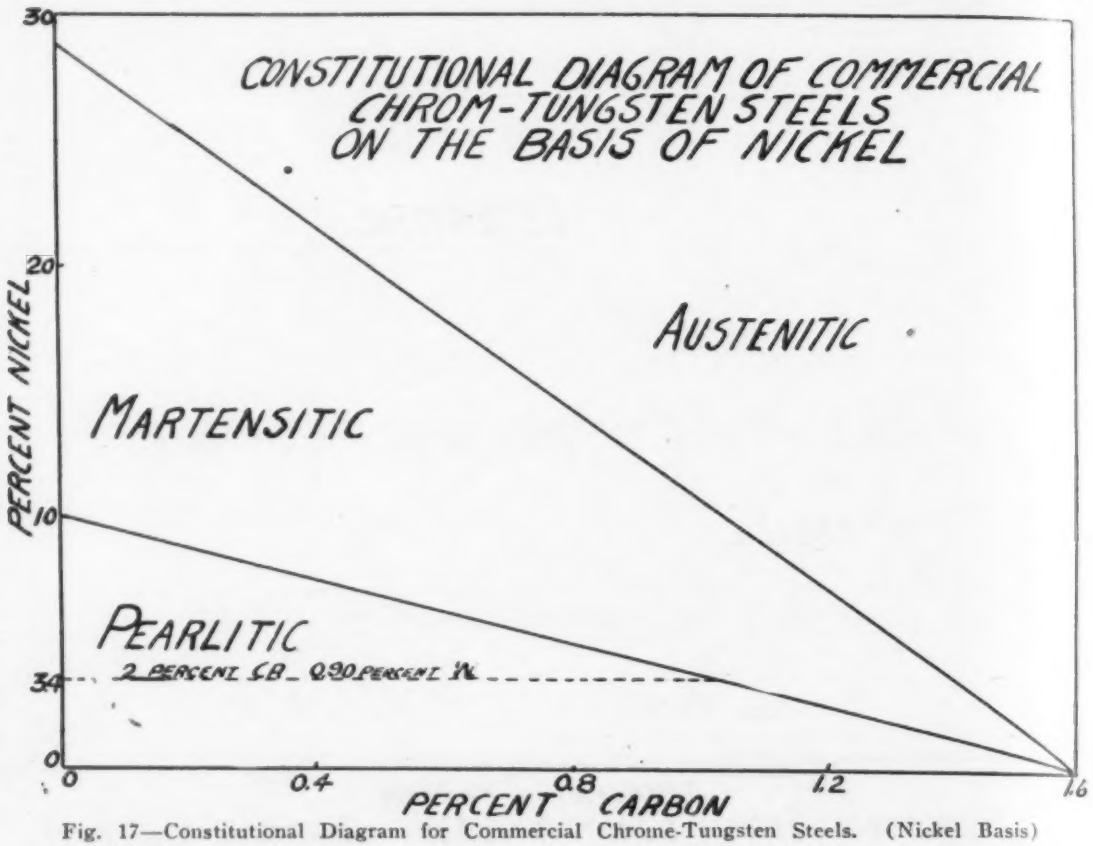
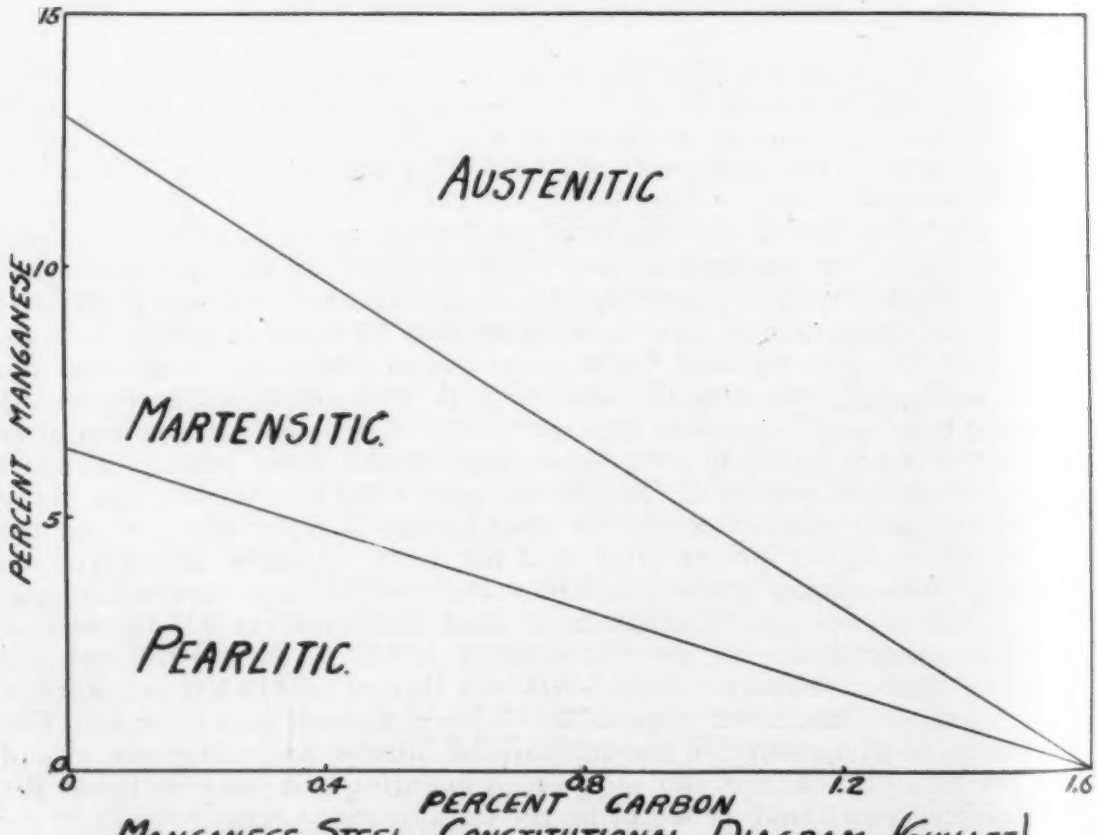


Fig. 17—Constitutional Diagram for Commercial Chrome-Tungsten Steels. (Nickel Basis)



MANGANESE STEEL. CONSTITUTIONAL DIAGRAM. (GUILLET)

Fig. 18—Constitutional Diagram for Manganese Steels

surface and internal defects. These are conditions that the mill producing the steel has in its control. In an attempt to make tonnage records, satisfy stockholders, and purchasing agents the quality of all alloy steel has not, in all cases, been as high as we would like to see. To be sure, within the past few years, purchasing agents have not been able to be overly deliberate in the purchase of steel. The demand for finished automobiles and other machines and apparatus using alloy steel has been so great that purchasing agents have taken what they could get. To meet the pressure placed upon them some mills, in fact all mills, have been tempted to lower standards of quality. That period, at least for the present, is past.

Influenced, the author believes, by just such a set of conditions as

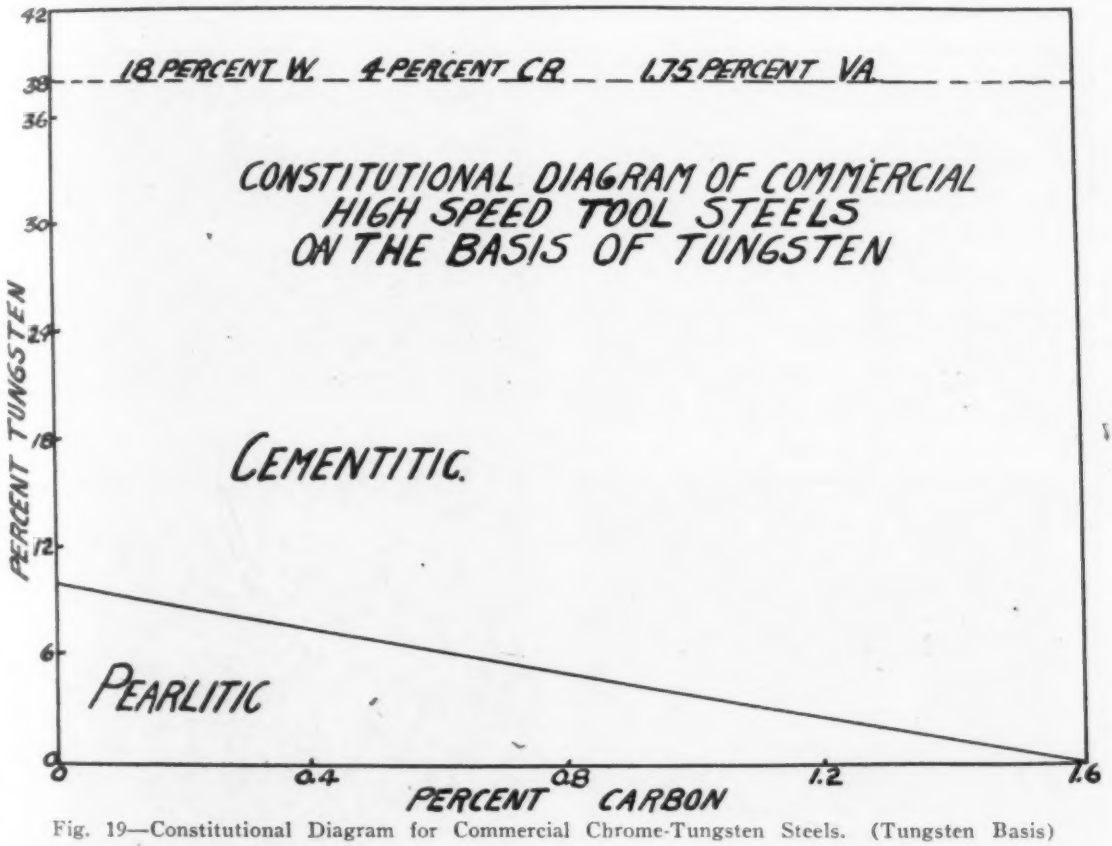


Fig. 19—Constitutional Diagram for Commercial Chrome-Tungsten Steels. (Tungsten Basis)

has been stated, one of the prominent metallurgists in the country has tended to turn toward plain carbon steel in place of the alloy steel used in the plants under his control. On the assumption that piped alloy steel is not much, if any, better than plain carbon steel, his stand is right. On the assumption that beginning with 1921 we may except to be able to buy alloy steel with practically full assurance regarding its freedom from piping, undue segregation, and surface defects, his position is wrong.

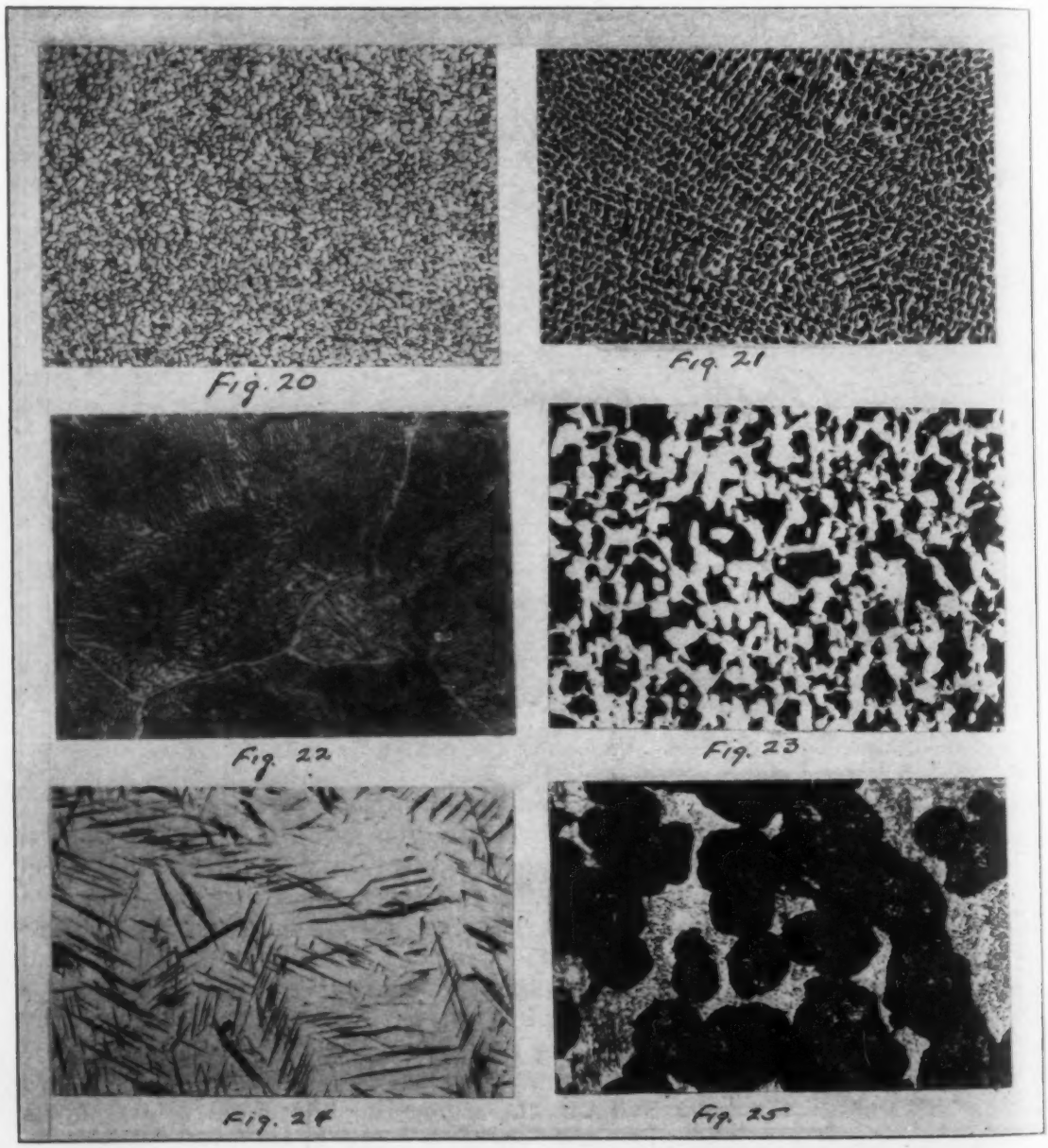
The statements just made are not a charge against our mills producing alloy steel. Such conditions as are wrong are chargeable to ourselves. Last summer those of us that were in the market for cars were placing all kinds of pressure upon the agents. They transmitted this pressure to the factories, and from there it was passed on. What is surprising, is that the quality of steel remained at such a high standard in spite of this pressure.

Factors of importance to the fabricator are ease of forging, ease of

machining and fool proofness in heat treatment. In this last field resistance to warping, resistance to the development of quenching cracks, a wide quenching range and a high drawing range are most desirable.

Finally, a factor so self evident that it has been left to the last is the ability, after suitable treatment, to get the desired properties. It is this last factor, the ability to cut down weight and retain strength, maintain strength with no sacrifice in ductility, increase hardness, increase resistance to shock, increase resistance to fatigue or to secure some other type or set of properties that has brought the special structural and fabricating alloy steels into such general favor and use.

Those who use alloy steel have, as a rule, definite ideas regarding



Photomicrographs of Steel Showing Various Constituents. Fig. 20—Largely Ferrite. Fig. 21—Cementite (White). Fig. 22—Pearlite. Fig. 23—Sorbite (Black). Fig. 24—Austentite (White) and Martensite (Dark). Fig. 25—Martensite (White) and Troostite (Dark).

the types they favor. It is surprising, though, that even with the large number of tests which have been made, and which are daily being made, no one class stands out as the type for a particular service. Possibly, on reflection, this condition should be true for differences in design, in manufacturing operations and sequences may, quite logically, call for different types.

A disappointing feature of the whole situation, however, is the absence of correlated data for the various types. Each individual plant using alloy steel may feel that it has such data but there are many plants whose sole reason for the use of a given steel is familiarity and relative acceptability in service. These, it is granted, are strong reasons and should not be thrust aside until after due assurance that a change will either lower costs, improve quality, or, possibly, accomplish both results. It is disappointing, though, to find plants that can speak only in generalities. It is unfortunate that they do not have concrete evidence to support their choices.

Much data which has been secured in the past is of little value because the conditions under which it was obtained were not the same. The manner in which the steel is made, the amount and the nature of the mechanical work done upon the metal and the temperature at which such work is done, the location of the test section in the ingot or bar, the size of the test bar and whether it is heat treated in the rough, in the semifinished or finished condition, the character of the finish machining upon the bar, the method of heating, including time in furnace, location in furnace and character of furnace gases whether neutral, reducing or oxidizing, the location and correctness of the pyrometer, the time of transference from the heating furnace to the quenching bath, the shape and size of the bath, the nature and temperature of the quenching medium, differences in drawing and differences in calibration and speed of operation of testing machines are all factors which play an important part in the properties obtained in the steels. The normal instruction of quenching a bar 0.505 inch in diameter in oil at 1450 degrees Fahr. and drawing at 900 degrees Fahr. does not tell all the story. It is because this is true that the discrepancies which crop up from time to time in steels of the same grade make their appearance.

The Society for Automobile Engineers is today engaged in a splendid piece of standardization along the lines just pointed out as being so badly needed. It is trusted that they may continue to make the progress which has been so auspiciously started.

As a final word we find in Ecclesiastes XXXVIII, 28, the following paragraph:

"The smith also sitting by the anvil, and considering the iron work, the vapour of the fire wasteth his flesh, and he fighteth with the heat of the furnace: the noise of the hammer and the anvil is ever in his ears, and his eyes look still upon the pattern of the thing that he maketh; he setteth his mind to finish his work, and watcheth to polish it perfectly."

It is that last word "perfectly" which should be our goal. Whether we are makers of steel, sellers of it or of allied products, consumers of it, or fabricators and heat treaters of it, let us approach it with a full understanding and in our contact with it do our part "perfectly."

MOLYBDENUM STEEL AND ITS APPLICATION

By M. H. Schmid*

(A Paper Presented Before the Washington Chapter)

While it is true that molybdenum structural steels were commercially developed during the world war, and through their development rendered possible great advancement in army and navy equipment and accessories, it is equally true that war conditions merely furnished the impetus for this development. The commercial application of molybdenum steels for industrial purposes was inevitable; the assurance of adequate and accessible domestic supply of this important alloying element allaying all fears as to the ability to meet future commercial demands.

That the earliest experiments in molybdenum steels were confined largely to tool and magnet steels is not surprising in view of the fact that molybdenum was not then known to exist in sufficient quantities to warrant its consideration, other than purely academic interest, for commercial structural requirements. It is surprising, however, to note that in spite of the then limited available supply of this alloying element, the earlier experimentation on structural steels was in most cases confined to material of a much higher molybdenum content than is considered advisable at the present time. It is also surprising that practically all study was confined to its direct effect in the ternary steels instead of more research on its indirect effect or additive and intensifying effect on other elements in the quartenary and more complex alloy steels. It is of course quite possible that research along the latter lines was pursued but not published. It is a fact, however, that exhaustive research directed by C. H. Willis established the practicability of the commercial application of molybdenum as an alloying element in the various types of alloy steels.

A review of the many types of steel on which the addition of molybdenum has a distinctly pronounced beneficial effect enables us to grasp the diversity of the application of molybdenum steels. Its effect is pronounced in straight carbon steels, chromium steels, nickel steels, chrome-nickel steels and vanadium steels. In straight carbon or nickel steels, by uniting with the ferrite additional strength is imparted without corresponding decrease in toughness. In steels containing chromium, probably through the formation of double carbides, additional strength and hardness is imparted together with beneficial effect due to any diffusion in the ferrite. The penetrative effect of heat treatment, especially in large sections, is decidedly pronounced.

I think most of us can recall the time when the selection of alloy steels for various products was based almost entirely on the physical characteristics obtainable. There is now a variety of types of alloy steels in which there is very little difference in physical properties, all of which will yield the necessary strength and factors of safety in the finished product. The present consumer of alloy steels, having at his command many types that are satisfactory so far as static and dynamic qualities are concerned, is influenced in his choice of material by the efficiency of the product in proper and economical functioning in the various manufacturing processes. From the manufacturing standpoint, he wants a steel which first of all has a tendency toward the minimum of inherent defects; he wants a steel which gives the most efficient response to the various thermal and mechanical manipulations to which it is subjected

*Metallurgical engineer, United Alloy Steel Corp., Canton, O.

in the numerous stages of processing from the raw material to the finished product.

Careful consideration of the following requirements should be given by the customer in his selection of an alloy steel:

(1) It shall meet such specifications as are imposed by the engineering department.

(2) The elements used in its manufacture shall be readily obtainable with assurance of adequate source of supply for the future.

(3) It shall not be subject to patent litigation.

(4) It must be entirely practicable as a commercially manufactured product of uniform quality.

(5) It must respond satisfactorily to various thermal manipulations with reasonably wide temperature ranges.

(6) It must respond satisfactorily to various mechanical manipulations.

We will not review these requirements in detail from the standpoint of molybdenum steels.

(1) *Specifications.* There is little need for a detailed discussion regarding physical characteristics. "Molybdenum Commercial Steels" published by the Climax Molybdenum Co. gives concise information as to just what physical properties may be developed on the various types of molybdenum steel. We know that the chrome-nickel-molybdenum steels used on Liberty motors for aircraft service met the most exacting specifications and records of tests on physical properties showed results superior to those obtained on any other types of steel used in this class of work. As far as the desired physical properties are concerned, it appears but necessary to select the particular type best suited for the purpose under consideration. For general requirements for automotive or machine construction, the chrome-molybdenum steels are usually recommended for special requirements it becomes necessary to use the more complex types, such as chrome-nickel-molybdenum.

(2) *Raw Materials.* The supply, present and future, of ferro-molybdenum for commercial production has been assured. Sufficient ore deposits, adequate for many years production have been established, with the necessary mining and refining capacity to take care of all future requirements. Four-fifths of the world's known available supply of molybdenum is contained within the borders of the United States. The present supply of chromium, the alloy most commonly used in connection with molybdenum is practically inexhaustible and is found in most every part of the world.

(3) *Patents.* The recent action whereby any alloy steel manufacturer in the United States may be licensed to produce chrome-molybdenum steels under patents during the life of same on a royalty basis which is so trivial as to have no bearing on the price of the steel, should relieve any fear as to litigation.

(4) *Manufacture.* That the manufacture of molybdenum steels is on a practical commercial basis has been well established. The first heat of electric furnace steel made by the United Alloy Steel Corp. was tapped Dec. 3, 1917, since which time this company has made in excess of 10,000 tons of ingots of various types, comprising carbon-molybdenum, chrome-nickel-molybdenum, etc. The first open-hearth heat of molybdenum steel was tapped by this company May 24, 1918, and since that time approximately 25,000 tons have been produced.

No serious difficulties are experienced in the various stages of proc-

essing, from melting and casting on through the rolling and cold drawing operations. The manufacture of molybdenum steel merely requires the same care as is exercised in the production of any well made type of alloy steel of similar potential properties—in fact less care than is necessary on many types.

Molybdenum is available as a furnace addition in two forms, as ferro-molybdenum and as calcium molybdate. In the ferro form it is most conveniently obtained and used with a molybdenum content of 50 to 60 per cent, although our company has very successfully used 70 to 80 per cent ferro-molybdenum. In the form of calcium molybdate we have a lower percentage of metal, averaging 35 per cent. The ferroalloy may be added in the open-hearth process as follows:

(1) All additions in the furnace as the charge is melting down.

(2) All additions in the furnace just prior to tapping (10-15 minutes).

(3) All additions in the ladle.

(4) Part addition in the furnace and part in the ladle.

In the manufacture of molybdenum steels at our plant we have thoroughly investigated all of the above methods and have adopted the first as standard practice because of the better diffusion and higher degree of uniformity in the finished product together with higher efficiency or minimized loss of the alloy.

It has been our experience that calcium molybdate is most satisfactorily added in sacks as the scrap charge is melting down, being so placed as to permit the partially molten scrap to cover or envelop the salt. Greater care is necessary with calcium molybdate than with the alloy in ferro form in order to prevent the draft of the furnace from pulling off part of the powdered molybdate addition and carrying it to the furnace walls, ports and checker chambers. The average loss of metal added in ferro form by the first method outlined above should not exceed 5 to 10 per cent, the loss tending toward the minimum where the same furnace or furnaces are used on successive heats, thereby reducing the purely mechanical loss. Just how this loss may be subdivided is worthy of some discussion. A slight mechanical loss is inevitable and we may assume it as running between 2 and 4 per cent, leaving an additional loss of say from 3 to 8 per cent unaccounted for. The author is not prepared to state just how this should be distributed. It is probably due to both oxidation and volatilization. Molybdenum additions in the ladle are generally inadvisable and where a high molybdenum content in steel is required, should be made only in the molten condition.

Of worthy consideration is the utilization of molybdenum steel scrap, which may be included in the furnace charge with a yield of approximately the same ratio as direct alloying additions.

No special comment is necessary regarding ferro-molybdenum and calcium molybdate charges in the electric furnace, where slagging, oxidizing and temperature conditions are under absolute control. Practically one hundred per cent alloy efficiency is possible.

The blooming and finish rolling operations on molybdenum steel require no special precautions other than those necessary on corresponding types of other alloy steels, and the practice, measured in per cent of available finished product, is higher than in most types of similar properties. The tendency toward a minimum amount of inherent defects, both

surface and subsurface, is very pronounced especially as compared with nickel and chrome-nickel steels.

While molybdenum evidently has no deoxidizing or scavenging effect, it has at the same time no deleterious effects on the working of the steel and a chrome-molybdenum steel should process as efficiently as the same type without molybdenum, and a chrome-nickel-molybdenum should process as efficiently as the same type without this additional alloy. Molybdenum steels as a class may be considered as more free from seams than nickel and chrome-nickel steels of corresponding potential values. It would be absurd, however, to claim that such defects in billets heal up or roll out in finishing mill operations.

Wide temperature ranges are available for rolling and forging, and while there is no appreciable difference in the amount of scalage, there is a marked advantage in the texture of the scale over that on nickel steels. The scale is a loose, nontenacious one, freely flaking from the steel showing no tendency to roll into the surface and result in pitting.

(5) *Thermal Manipulations.* Molybdenum steels as a class may be subjected to unusually wide temperature ranges for both hot working and heat treating. This applies particularly with respect to the more generally used chrome-molybdenum types which will satisfactorily withstand considerably higher temperatures than the corresponding types of nickel and chrome-nickel steels. Forging companies report that chrome-molybdenum steels flow better in the dies than other types, which advantage is probably due to a large extent to the use of higher working temperatures. The author cannot conscientiously credit molybdenum steels with less scalage loss, but it is certainly true that less difficulty is encountered in forging operations on account of the ease with which scale loosens from the bars in carbon-molybdenum and chrome-molybdenum types. Cleaner forgings are obtained and tumbling and pickling charges are minimized.

The outstanding features relative to the heat treatment of molybdenum steels are the extremely wide quenching ranges available for practical heat treatment; the excellent penetrative effect of such treatment on large sizes; and the broad drawing range causing but slight modification in physical properties, this due to the retarded disassociation and reversion to normal state upon heat application after quenching. Data has been published by the Crucible Steel Co., the Carbon Steel Co. and the United Alloy Steel Corp., showing uniformity in static properties through a wide range of quenching temperatures, but without information as to comparisons on dynamic properties.

To show that impact as well as static properties evidence no marked variation with quenching temperatures ranging from 1500 to 2000 degrees Fahr. inclusive, I have taken average results from a series of recent experiments in our laboratories on chrome-molybdenum steel analyzing as follows: Carbon, 0.27; manganese, 0.66; sulphur, 0.036; phosphorus, 0.018; silicon, 0.08; chromium, 0.83; molybdenum, 0.42 per cent. The size treated was 7/8-inch round and all tests were drawn at 1050 degrees Fahr., after quenching in water at the temperature indicated. The tests were as follows:

Quenching Temperature Degrees Fahr.	Elastic Limit pounds per square inch	Tensile Strength, pounds per square inch	Elongation, per cent	Reduction of Area, per cent	Brinell	Izod
1500	140,000	163,500	18.5	62.7	319	58
1600	139,500	161,700	17.0	63.1	321	62

1700	138,400	160,400	17.5	61.7	321	60
1800	138,300	158,500	18.0	61.5	319	61
1900	139,600	159,600	16.8	57.9	317	56
2000	140,000	157,000	17.0	59.0	317	55

Striking evidence of the penetrative effect of treating as well as the high drawing temperatures available for attainment of high physical properties is manifested in our type "LM", chrome-nickel-molybdenum steel, used for crankshafts and connecting rods in aircraft work. The analysis range of this type is: Carbon, 0.22-0.30; manganese, 0.50-0.70; sulphur, 0.035 maximum; phosphorus, 0.030 maximum; silicon, 0.10-0.20; chromium, 0.70-0.90; nickel, 2.75-3.25; molybdenum, 0.30-0.50 per cent. Heats running 0.25-0.30 per cent carbon were selected for crankshafts, and those running 0.22-0.25 were used for connecting rods. Physical results taken on a full size prolongation, approximately 4 inches diameter, and averaged from 28 tests taken at random showed:

Elastic Limit: 130,000 pounds per square inch.
Ultimate Strength: 142,000 pounds per square inch.
Elongation in 2 inches: 20.5 per cent.
Reduction of area: 65.0 per cent.
Izod: 67.
Brinell: 303

On a series of tests on 2 inches round, taken from the same type, after quenching in oil at 1450 degrees Fahr. and drawing as indicated, were obtained:

Drawing Temperature, degrees Fahr.	Elastic Limit pounds per square inch	Ultimate Strength pounds per square inch	Elongation per cent	Reduction of Area, per cent	Brinell	Scleroscope
500	233,000	249,800	14.0	46.8	455	54
900	170,000	189,200	16.0	51.6	363	45
1000	161,000	180,700	18.5	58.3	344	43
1100	149,000	166,800	18.5	60.0	328	41

These results show that there is but slight change in physical characteristics between the 900 and 1100 degree Fahr. drawn.

On type "Mo. 102", an oil hardened gear steel, were obtained a tensile strength in excess of 200,000 pounds per square inch for all drawing temperatures up to 1000 degrees Fahr., and an elastic limit in excess of 200,000 pounds per square inch for all temperatures up to 900 degrees Fahr. Tests on standard 0.505-inch specimens, quenched in oil at 1450 degrees Fahr. and drawn at 400 and 1000 degrees Fahr. respectively, gave:

Drawing temperature, degrees Fahr.	Elastic Limit pounds per square inch	Tensile Strength pounds per square inch	Elongation per cent	Reduction of Area, per cent
400	302,000	336,600	10.0	22.4
1000	190,000	202,200	15.5	50.1

(6) *Mechanical Manipulations.* The most important mechanical operations to which steel is subjected in the manufacture of the finished product are cold pressing, forming and heading, and machining. Efficient response in the operations involving cold flowing of metal effects savings in fabricating costs resultant from minimization of rejections in semi-finished and finished parts, as well as maintenance costs on dies and tools. The merits of molybdenum steel for this purpose have been established through the results obtained on carbon-molybdenum and chrome-molybdenum types in the cold forming and pressing operations in the manufacture of automobile frames, die steel wheels and rear axle housings;

through production of cold headed parts on the chrome-molybdenum types, and through cold upset balls on the high carbon, chrome-molybdenum ball and race types

The molybdenum steels have better machineability than other alloy steels of equal physical properties. This has been established by the production results obtained on several thousand tons processed into rear axle drive shafts and on which no machining difficulties were experienced on shaft heat treated to conform to a 300-340 Brinell specification. On a heat made by the United Alloy Steel Corp. for one of the large automobile companies and put into steering knuckles and front axles, a report was received to the effect that tool grinding costs were but one-third as high as on 3½ per cent nickel steel of the same hardness and with corresponding shop production. Front axles with Brinells up to 340 maximum machined as well as chrome-nickel steel axles of 302 Brinell.

The scope of application of molybdenum steels appears wider than that of any of the other types of alloy steels. While the greater portion of the molybdenum steel manufactured to date has been used in automotive forgings and pressed metal parts, its excellent properties have likewise warranted its use in a variety of other parts, embracing railroad forgings and track bolts, armor plate, air flasks, agricultural implements, shovels, machinery forgings and piston rods, various edge tools, etc. The general utility of molybdenum steels promises an increased demand in a well diversified field.

THE ESSENTIALS OF MODERN PYROMETER EQUIPMENT

By H. G. Hall*

(A Paper Presented by Title at Philadelphia Convention)

In a pyrometer steel treaters have been asking for an instrument that is accurate, but the tendency seems to be to sacrifice considerable in the other features to obtain accuracy. While it is admitted that accuracy is of prime imporance, other features are to be considered. The subject naturally divides itself into three distinct parts: (1) The instruments; (2) the leads and (3) the thermocouples. It has been found that the instrument to give the most satisfactory results should have a resistance of about 250 ohms across binding posts. This is for plant use of course and seems high enough to eliminate the troubles due to changes of external resistance. Careful tests have shown that just as accurate results can be secured with this amount of resistance as is found in the higher resistance meters, thus it is not necessary to sacrifice further ruggedness for the additional ohms resistance.

The indicating instrument should have a very clear and readable scale, instruments supplied with a spotter being advantageous for shop work, particularly when the temperature is to be maintained constant. An instrument void of chamber error certainly is one of the very important features to be remembered in making the selection because of the fact that some meters have a chamber error amounting as much as 40 degrees which makes them useless to the steel treater.

The discussion might be carried further as to whether the instrument should be of the suspension type or of a double or single pivot movement. The fact is, that it is necessary to have an instrument that will stand the ordinary amount of vibration found in a shop. The highest grade of double pivot movement has answered the requirements very

*District manager, the Bristol Co., Chicago.

well as it seems to be least affected by vibration. Careful tests show that this type of instrument gives the desired degree of accuracy.

The chamber error has been found to be one of the important causes for trouble. This is a very annoying situation because many do not know what is causing the inaccuracy and it is difficult to correct without replacing the meter.

While the recording type instrument is used in some cases as an indicator as well as a recorder, the most important factor is simplicity of design. It must at the same time make clear and readable records. Obviously, a steel treater does not want a recorder that will require constant supplying of repair parts and in this way, take his attention from other work, which involves considerable annoyance and added expense.

It has been found that recorders giving the continuous automatic records are to be preferred to those that give numbers from which the curve can be drawn later. The charts made should be easy of access and easy to file, thus the principal feature in connection with the use of the recording pyrometer should be simplicity of construction. Surely the simplest mechanism, other parts being equal, will require the least care and the least amount of rechecking.

In considering leads or couple extensions one must consider the proper kind of insulation for the wire to meet the plant conditions. In many cases it is necessary to use asbestos-covered wire where rubber-covered wire would not be satisfactory, and vice versa. The couple extension is one of the important features of every pyrometer equipment. A number of steel treaters using pyrometers have installed in their plants what are called "compensated leads" although the term is not commonly understood.

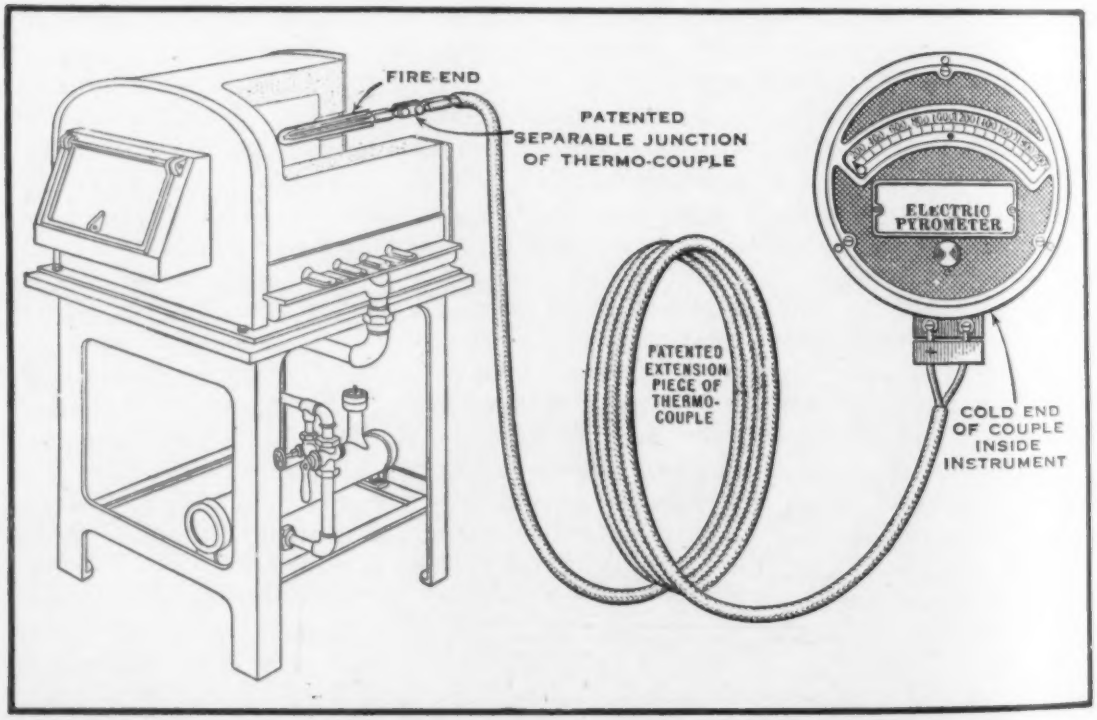


Fig. 1—Diagram of a Pyrometer Installation Showing the Fire End of the Thermocouple Inserted in the Furnace

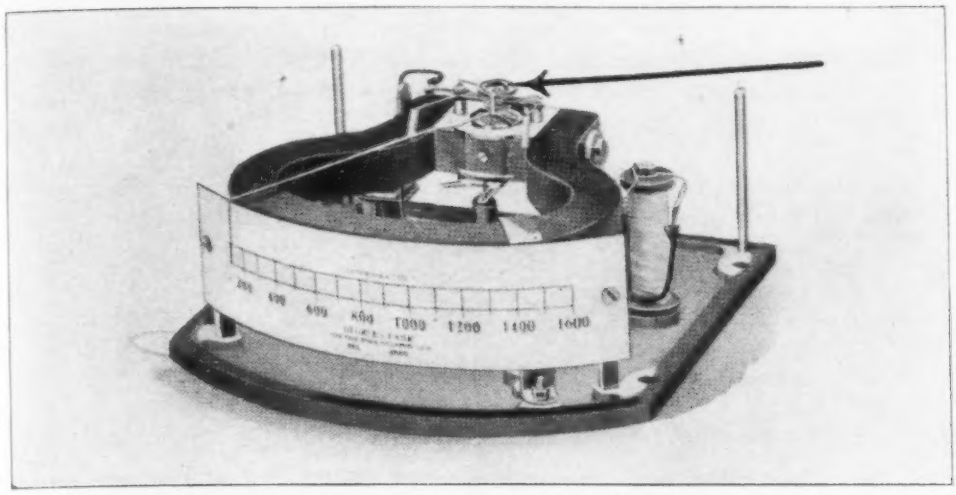


Fig. 2—Interior View of a High-Resistance Indicating Pyrometer Showing the Compensator Denoted by Arrow

Certainly this term should be defined clearly thus possibly the term flexible couple extension carries the idea more clearly than compensating leads. The latter seems a misnomer because these leads do not actually compensate. This brings us to the consideration of the error due to the cold junction variation in temperature. On some pyrometer equipments the cold junction is buried in the ground and on others it is put in the hot water or steam jackets; and on still others it is put in regulating boxes controlled by lamps. Recently some steel treaters have put the cold end in a box of a special powder in which the cold end does not vary more than plus and minus 5 to 10 degrees Fahr. While it is true that these methods of installation have been satisfactory under certain conditions, they have not met the universal requirements for eliminating the error due to the cold end. It is very expensive under many conditions to bury a cold end for blasting in rocks or concrete often is required. Water jackets will leak in time and cold end regulating boxes are just an additional part of the equipment to require care. It must be borne in mind constantly in using the pyrometer that the electromotive force developed depends upon the difference in temperature between the cold junction, which is outside the furnace, and the hot junction which is in the furnace.

An internal cold junction compensator has been developed and tried which operates automatically and does away with the necessity for burying the cold end in the earth and eliminates the use of any other outside means for regulating the temperature at the cold end. It is enclosed in the instrument itself, one end of the internal spiral compensator—for such it is called—being attached to the pointer while the other end is securely fastened to the instrument. The method of using the compensator is illustrated in Fig. 1. It is satisfactory for use on either base metal or precious metal couples.

Of course, in using this compensator it is necessary to run the same kind of material that is in the base metal couple to the instrument itself. In the case of an installation of an instrument with a compensator for a manufacturer of crank shafts for automobiles, the temperature of the oven was maintained at 40 degrees Fahr. and readings were taken across the entire scale, the readings being within ¼ to 1 per cent. Many other companies are using this compensator with similar accuracy.

It is also very gratifying to find that this compensator has worked out so satisfactorily because it is the result of many years of experimentation on a suitable device for accomplishing this result. Credit for the development work is due to William H. Bristol, of The Bristol Co., Waterbury, Conn.

Elimination of the chamber error in the instrument and the error due to the cold end temperature, overcomes two of the chief objections to the use of the thermoelectric pyrometer, and makes it possible to use this instrument for very low ranges of temperature with a high degree of accuracy. Accuracy well within 1 per cent for ranges of temperature is secured over the entire scale where the maximum reading of the scale is only 600 degrees Fahr.

In cases where a previous metal couple is used, the platinum wires are not run to the instrument but substitute patent alloy wire is used that carries the cold junction to the instrument and serves the same purpose for shop use as if the platinum were used for the entire length. The steel treater interested in accurate results from his pyrometer can obtain a great deal of satisfaction in knowing that his cold end errors are entirely eliminated. In other words the equipment is operated as though it had no cold end.

The diagramatic illustration, Fig. 1, shows a "fire-end" or thermocouple in a furnace, a length of flexible extension of the same material as the thermocouple extending to and inside of the indicating instrument. Fig. 2 is an interior view of a high-resistance indicating pyrometer, and shows the spiral of differential thermostatic metal which acts through the control spring of the indicating power and automatically changes the ten-

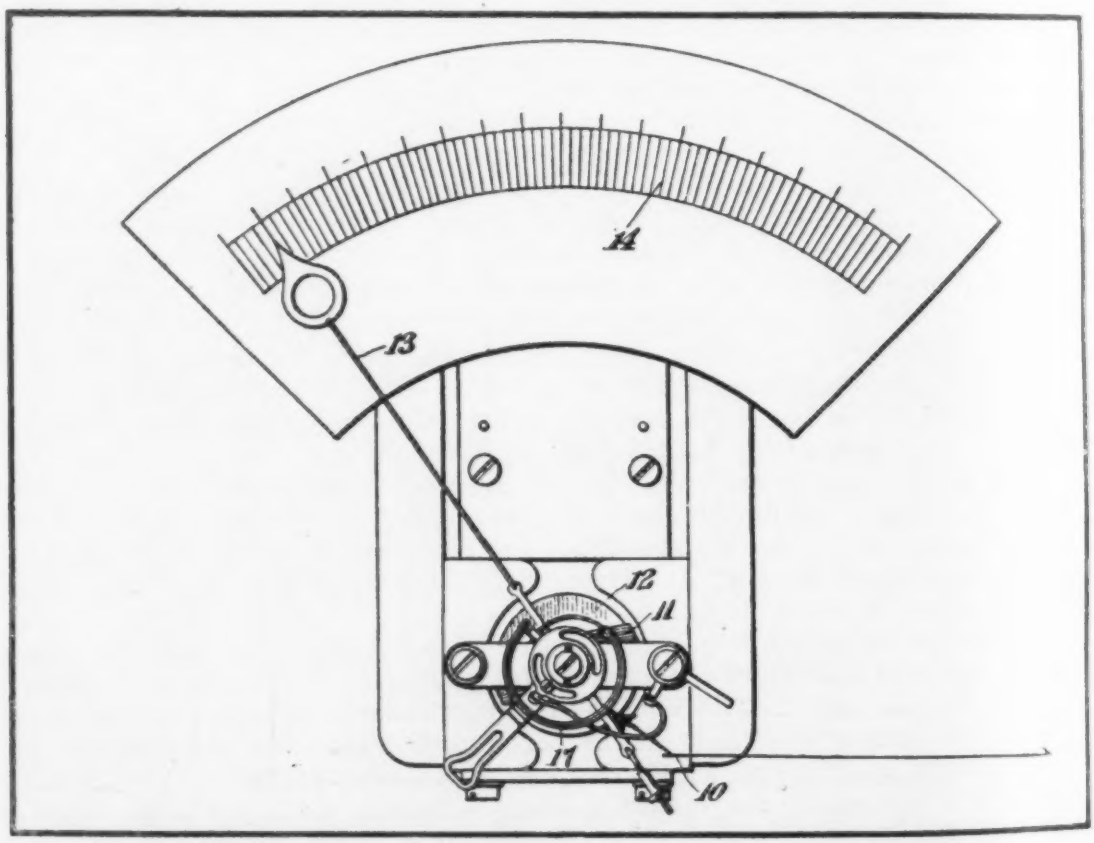


Fig. 3—Details of the Compensator Construction with Arrow Pointing to Compensator

sion on this spring so that the position of the indicating arm will continually correspond with the graduations on the scale and at the same time agree with the temperature changes of the room.

In Fig. 3 the details of construction of the compensator are more clearly shown. The indicating arm 13 is operated by the usual moving coil 11. A small portion of the control spring 12 is shown, but instead of the end of this spring being secured to the abutment, it is attached directly to the end of the spirally curved piece of thermostatic metal 17 and the other end of this thermostatic coil is carried by an adjustable abutment allowing for initial adjustment of the indicating pointer, to make its position on scale agree with that of room temperature.

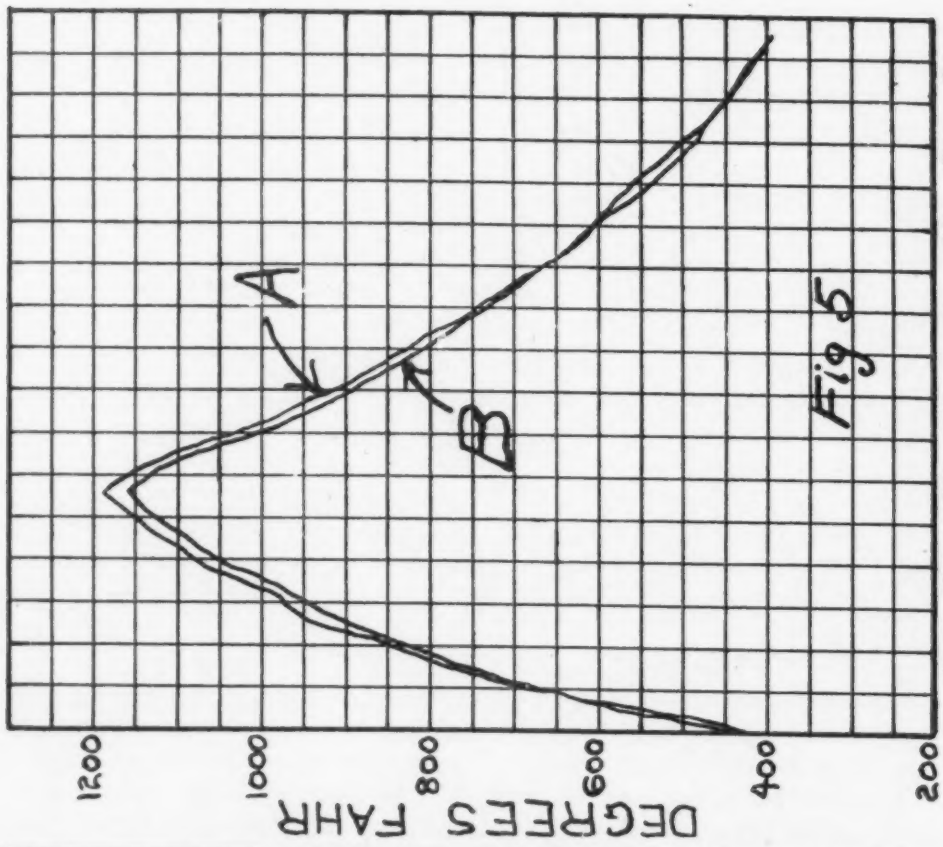
The temperature variations of the room cause the thermostatic spiral to wind up or unwind, maintaining the correct position of the indicating arm, regardless of room temperature. When the thermoelectric couple with extension-piece, as illustrated in Fig. 1, is carried into the compensated instrument, no corrections are necessary for the thermocouple cold end temperatures at any point on the scale. The compensator also may be made to serve a double purpose, since by a slight variation of its length it may be made to correct automatically for the temperature coefficient of the wire forming the moving coil of the millivoltmeter.

Fig. 4 shows curves *A* and *B* and is a comparison of readings of a laboratory potentiometer and a compensated pyrometer. The platinum couple was used with the potentiometer with the cold junction maintained at 32 degrees Fahr. in the bath. The temperature of cold junction of the pyrometer was maintained constant at 70 degrees Fahr. In Fig. 5 the temperature of the cold junction of the pyrometer was maintained at 130 degrees Fahr. in the oven while the cold junction of the potentiometer was maintained at 32 degrees Fahr. as in the case of Fig. 4. These readings were taken by an automobile manufacturer and illustrate the accuracy of the compensated pyromoter, the difference between the two instruments being practically constant throughout.

It is very important in the use of proper thermocouples that the couples produce the same electromotive force although the wires may be almost burnt off. Of course, in case the thermocouple does not give the same electromotive force, an error will occur in the readings, but with the advances made in manufacture of thermocouple alloys, this source of error has been overcome.

Although shunted thermocouples have been used with some success, the practice of using this idea as universal is not advisable because of the errors which are certain to result. The chief difficulty is that under most conditions the fire end is not always inserted the same distance into the furnace or tempering bath. With the advances made in developing alloy metals it has been found more practical to use base metal couples of selected material. These can be secured easily with a guarantee that readings will be within plus and minus 3 degrees Fahr.

The cost of thermocouple upkeep is, of course, important but this can be reduced very appreciably by making a thorough and careful study of the conditions. This includes study of the gases that are emitted from the fuel, as the oxidization of the steel or other articles in the furnace takes place. One prominent automobile manufacturer whose couple expense on about 500 couples constantly in use was about $1.00 per month, by very careful investigation of the conditions and proper protection of



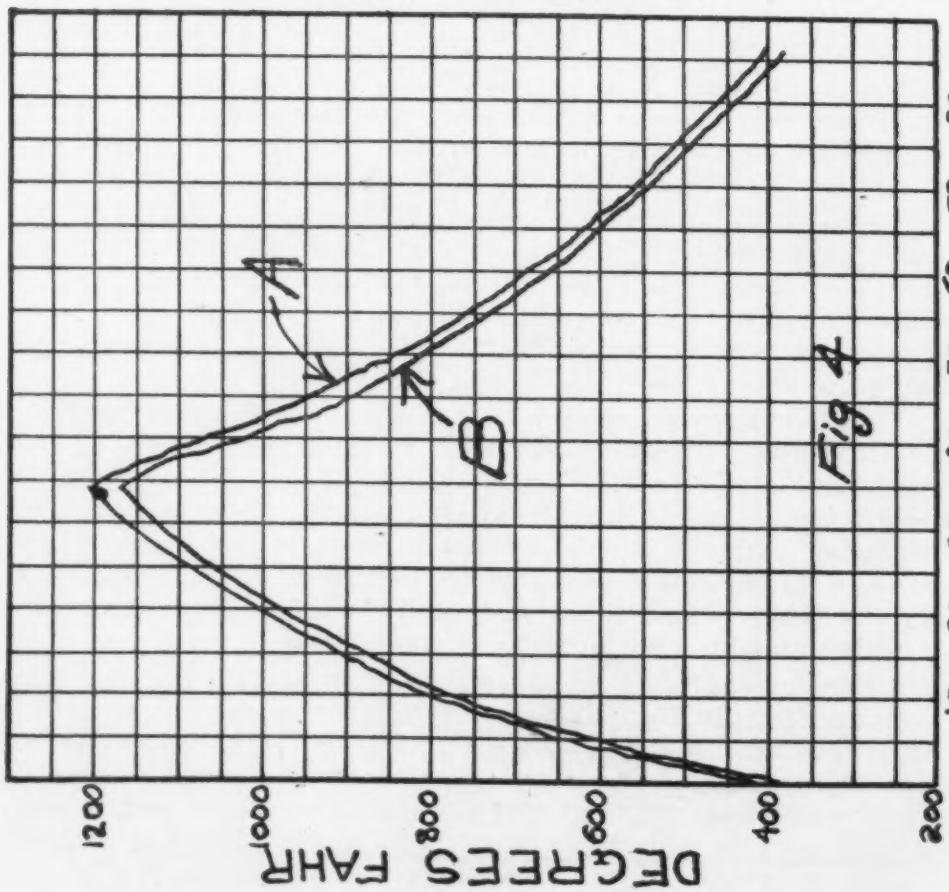


Fig. 4—Comparison Curves of Readings of Laboratory Potentiometer *A* and Compensated Pyrometer *B*. In the First Curve Cold Junction Maintained at 32 Degrees Fahr. and in Second Curve Maintained at 70 Degrees Fahr. Fig. 5—Same as Fig. 4 Except Cold Junction of Pyrometer Is Maintained at 130 Degrees Fahr. Both Fig. 4 and Fig. 5 Show an Almost Constant Difference Between the Curves

the thermocouple, reduced this cost to $0.27 a month. In this case, the manufacturer was using precious metal couples.

A manufacturer of roller bearings, who is using the potentiometer system, states that his couple upkeep was $12.00 per year, which is not excessive for platinum couples. This cost includes only maintenance expense for the couples and not the maintenance on complete pyrometer equipment whereas the case just mentioned of 27c per month includes maintenance on the entire outfit. In the former instance the upkeep of the entire equipment is included. Here the galvanomter system was used. From all the data the author was able to obtain, it is evident that the upkeep on the potentiometer systems were far in excess of the maintenance cost on the galvanometer system especially where potentiometer recorders were in use.

RELATION OF THE HIGH TEMPERATURE TREATMENT OF HIGH SPEED STEEL TO SECONDARY HARDENING AND RED HARDNESS

By Howard Scott*

High speed tool steel metallography presents certain anomalies, the explanation of which is not clear from the usual conceptions of the mechanism of hardening in simple carbon steels, as, for example, the familiar polyhedral structure of properly quenched high speed steel, which is often called austenite, although its physical properties are largely those of martensite. The explanation of such anomalies and a better understanding of the fundamental nature of high speed steel is becoming more and more important as the peak of development is being reached. It is even probable that future improvements will be largely in the technique of treatment and the adjustment of compositions to meet special requirements, in which cases fundamentals are of highest importance.

From this angle the problem of developing high speed steel is one of constitution and not composition. In spite of a wide variety of compositions, the general characteristics are very similar. The most effective method of attack, therefore, is through the study of a number of the physical properties of a high speed steel and their correlation with the corresponding characteristics of simple carbon tool steel, the recognized reference standard. The relations for carbon steels between heat treatment, microstructure, and physical properties have been rather thoroughly studied and are summarized in another paper.[1]

To make the proposed correlation, the microstructure, hardness, density, magnetic properties, and thermal characteristics of a typical high speed steel as affected by various treatments were studied. The variety of properties investigated necessitated the co-operation of several other laboratories of the Bureau of Standards; H. S. Rawdon prepared the micrographs, E. L. Peffer made the density determinations, R. L. Sanford the magnetic tests, F. H. Tucker the chemical analyses, Miss H. G. Movius prepared the thermal curves, and several assistants aided in the work.

The previously published researches related to the present one are

*Assistant physicist, Bureau of Standards, Washington.

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[1]See a paper "Thermal Changes Accompanying the Heating of Hardened Carbon Steels," by Scott and Movius which will appear in an early issue of TRANSACTIONS.

those of Edwards and Kikkawa,[2] Carpenter,[3] Yatsevich,[4] Mathews,[5] and Andrew and Green.[6]

Edwards and Kikkawa determined the effect of tempering temperature on the brinell hardness of two series of chrome-tungsten steels of constant carbon content, chromium being variable in one series and tungsten in the other. A constant hardening temperature of 1350 degrees Cent. was used with one exception, and the density changes of one representative composition were determined. This work represents the most important contribution to date to the study of the physical properties of high speed steels.

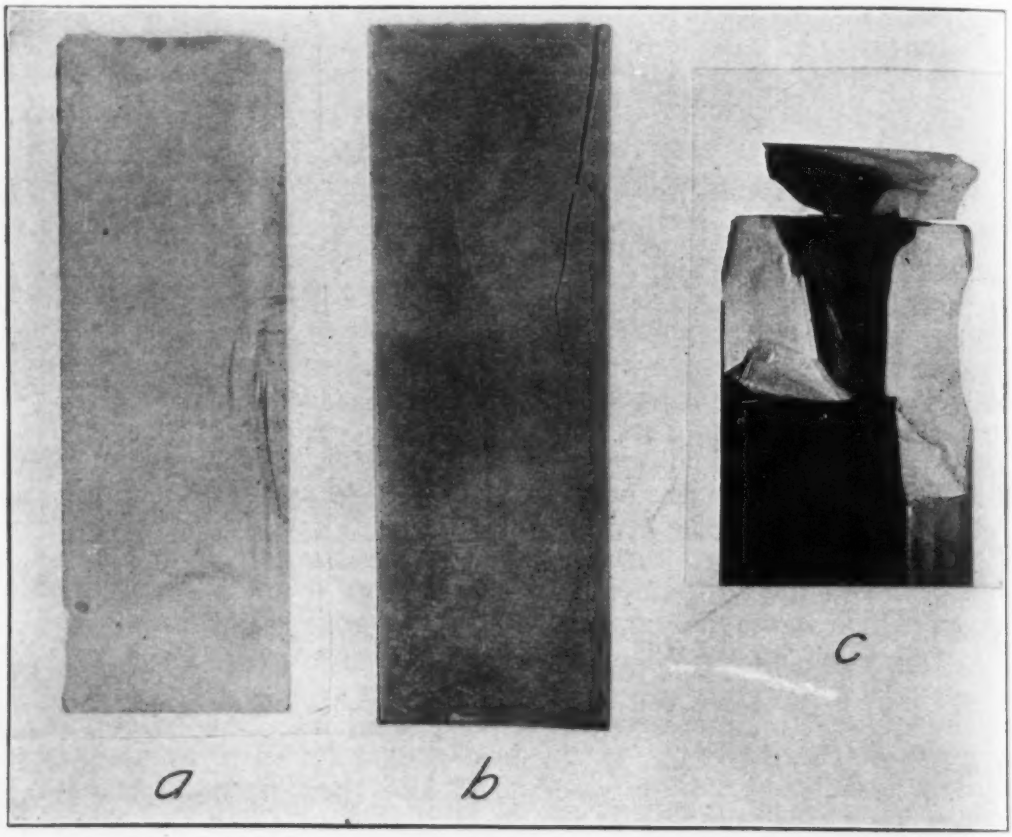


Fig. 1—Hardening cracks in high speed steel. Specimens of steel *B*, 1 x ⅝ x 3 inches, were hardened as follows: *a*, Quenched in oil from 1030 degrees Cent., surface of fracture parallel to 1 x 3-inch surface; *b*, cooled in air from 1050 degrees Cent., cracks perpendicular to 1 x 3-inch surface; *c*, quenched in oil from 1050 degrees Cent., fracture parallel and at 45 degrees to 1 x 3-inch surface.

Carpenter, Yatsevich, and Andrew and Green studied the critical ranges of high speed steels as affected by maximum temperature and rate of cooling.

Mathews summarized his wide experience with cutting and physical tests of high speed steel and reviewed developments since the classic experiments of Taylor and White.

These papers represent work on high speed steel of a wide variety of compositions and treatments, so that it is very difficult to establish any relation between the various properties studied. The present work is,

[2]Edwards and Kikkawa, Journal, Iron and Steel Institute, 92, page 6; 1915.
[3]Carpenter, Journal, Iron and Steel Institute, 67, page 433, 1905; 71, page 377; 1906.
[4]Yatsevich, Revue de Metallurgie, 15, page 65; 1918.
[5]Mathews, Proceedings, American Society for Testing Materials, 19, page 141; 1919.
[6]Andrew and Green, Journal, Iron and Steel Institute, 99, page 305; 1919.

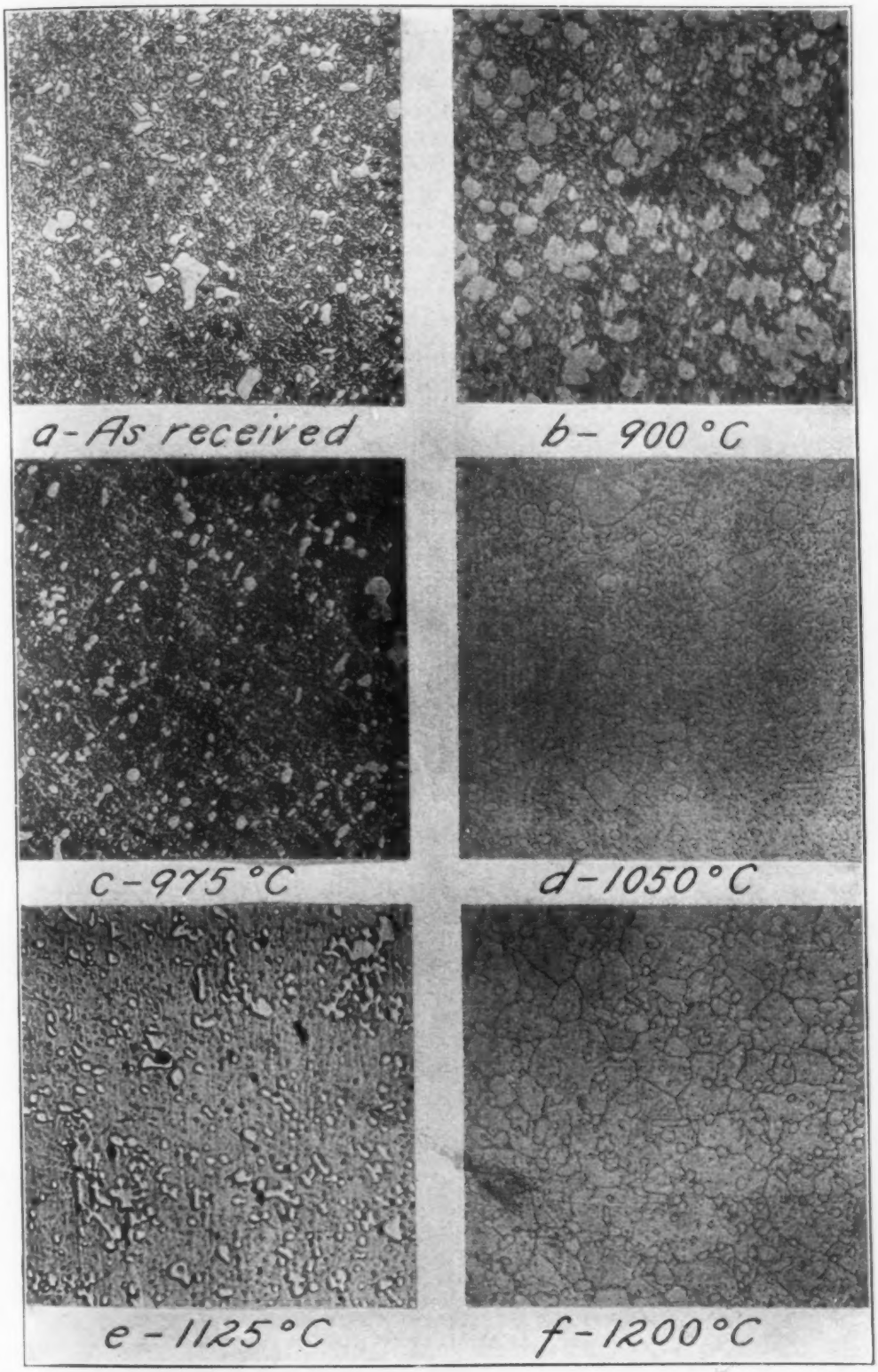


Fig. 2—Microstructure of specimens of steel *A* quenched from temperatures noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, Annealed; *b*, 900 degrees Cent.; *c*, 975 degrees Cent.; *d*, 1050 degrees Cent.; *e*, 1125 degrees Cent.; *f*, 1200 degrees Cent.

therefore, confined to one representative type of modern high speed steel.

For the purpose of this investigation tests were made on a standard type of high speed steel, chosen because it shows secondary hardening definitely. Unfortunately, sufficient material of one composition was not available, so that another composition was used also, this being purchased to duplicate the first as nearly as possible. As seen from the chemical composition given below, the two steels are very similar except in carbon content, which is low in the B steel for the brand used. As pointed out later, the lower carbon content, apparently, is responsible for a poor steel. The results of chemical analyses of high speed steels are as follows:

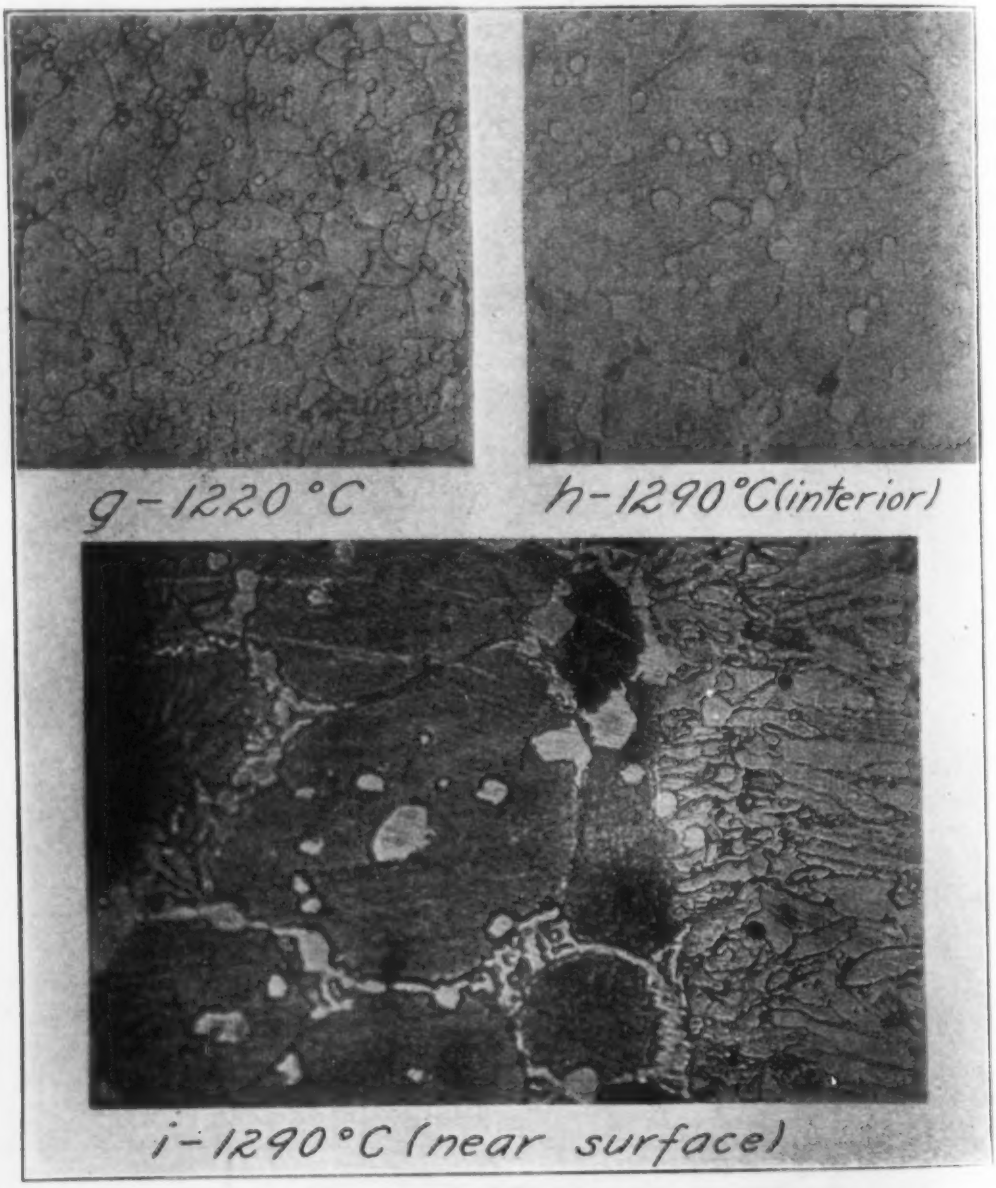


Fig. 3—Microstructure of specimens of steel *A* quenched from temperatures noted. Specimens x 500. Etched with 2 per cent nitric acid. *g*, 1220 degrees Cent.; *h*, 1290 degrees Cent., interior; *i*, 1290 degrees Cent., near surface.

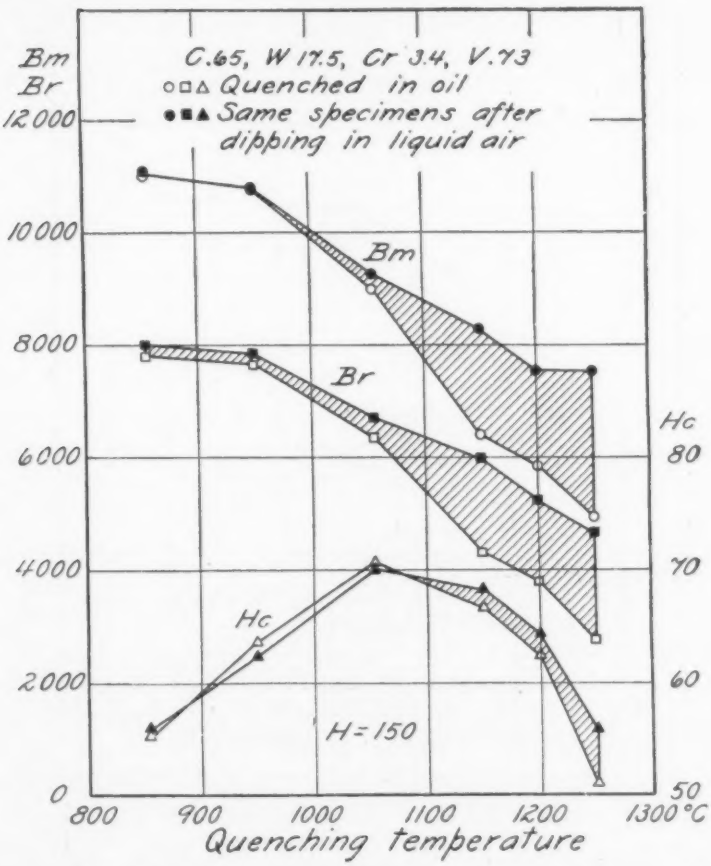


Fig. 4—Relation of quenching temperature and subsequent treatment in liquid air to maximum induction, residual induction, and coercive force of steel *B*.

Steel No.	Carbon	Manganese	Silicon	Tungsten	Chromium	Vanadium	Phosphorus	Sulphur
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
A.....	0.77	0.25	0.47	17.8	3.5	0.74	0.020	0.03
B.....	0.65	0.31	0.17	17.6	3.4	0.73	0.004	0.04

For hardening, the specimens were placed in an electrically heated alundum tube furnace in which charcoal or illuminating gas was burned to prevent excessive oxidation. The specimens were slowly brought up to temperature and held there 15 minutes before quenching. The quenching medium was a light mineral oil. Tempering consisted of heating for 15 minutes in an oil bath for temperatures up to 250 degrees Cent., in a nitrate bath up to 600 degrees Cent., and in a chloride bath for higher temperatures. The use of these baths assured a uniform temperature quickly reached. All high temperature measurements were made with platinum thermocouples.

The specimens were cut from a 1-inch square bar (steel A), and a 1 x ⅝-inch bar (steel B), both factory annealed. The magnetic test specimens were of 1 centimeter square cross section, the hardness specimens were of 1 x ¼-inch (steel A), and 1 x ⅝ inch (steel B) section, and the density specimens about 1 x 1 x ½-inch, as shown in Fig. 7, and about ½-inch face cubes, shown by Fig. 5. Specimens for micrographs were taken from the ends of the hardened magnetic test pieces.

In hardening, both steels usually cracked when quenched from the

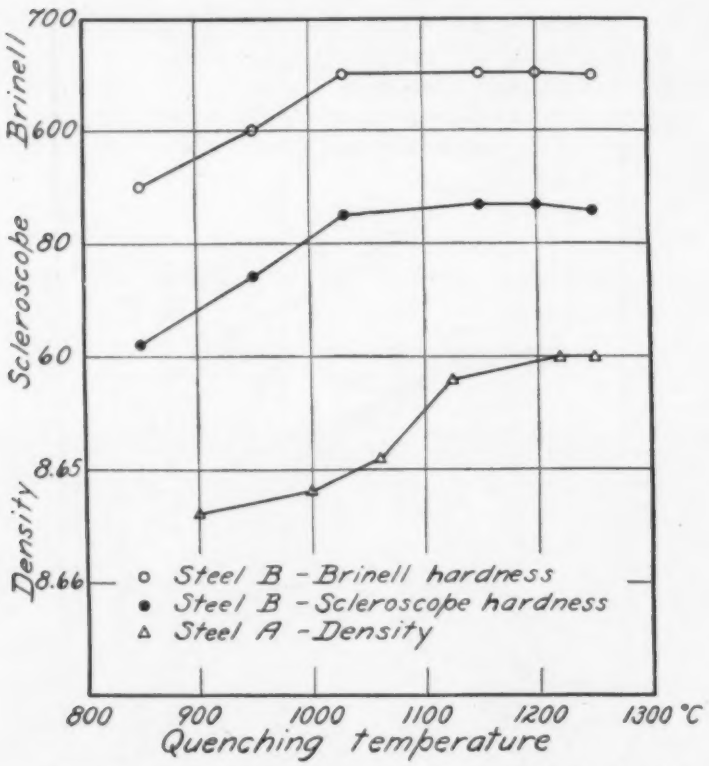


Fig. 5—Relation of quenching temperature to Brinell and scleroscope hardness of steel *B* and to density of steel *A*.

region of 1050 degrees Cent. The cracks followed the contour of the specimens, thus indicating that they were characteristic of the steel and not due to inclusions. The cracking was particularly severe in the case of the low carbon steel B, photographs of typical samples of which are shown in Fig. 1, a, b and c. This steel cracked also on cooling in air from 1050 degrees Cent. It was, however possible to obtain specimens on which the physical measurements could be satisfactorily made in spite of the cracks.

The density measurements were made by the usual method of weighing in air and in water, the specimens being dipped in alcohol prior to immersion in water to insure the absence of bubbles. The magnetic measurements were made in a long solenoid, corrections being made by the use of shearing curves. Other tests were made by the usual standard methods.

It has long been recognized that raising the quenching temperature increases the cutting efficiency of a high speed steel tool, so that the highest temperature short of fusion is the best. Observations were therefore made to determine the effect of quenching temperature on the properties under consideration to obtain evidence as to the nature of the constitutional changes.

The microstructure of steel *A* as quenched from several temperatures is shown in the micrographs of Figs. 2 and 3, the magnetic properties in Fig. 4, lower curves of shaded areas, and the density in Fig. 5. The effect of quenching temperature on the brinell and scleroscope hardness of steel *B* is also shown in Fig. 5.

These data permit of a classification of the quenched specimens into two groups according to the nature of their physical characteristics. The

properties of the first group, quenched from temperatures up to about 1100 degrees Cent., vary in a manner distinct from those of the second group, quenched from above that temperature. Besides the change in slope of the curves, the physical properties of the two groups are affected differently on cooling below ordinary temperatures. Thus the magnetic properties of the specimens quenched from the high temperatures are markedly increased as shown by Fig. 4, upper curve of shaded area, by immersion in liquid air, while the specimens quenched from the low temperatures remain practically unchanged. This is indicative of a constitutional difference, other than a continuously changing one, between the specimens of the two groups and has an important bearing on the anomalies of high speed steel.

To distinguish between these two groups, specimens quenched from the lower temperature range will be referred to as given the low temperature treatment, and those from the upper range as given the high temperature treatment.

The microstructure of the samples given a low temperature quench is obscured by the excessive amount of free carbide imbedded in the apparently structureless matrix. The microstructure of the specimens of this series will be called martensite from their physical characteristics, but it must be recognized that this may be a misuse of the term, depending, of course, on its definition. The specimens quenched from the high temperature range show well defined grain boundaries in a structureless matrix containing little free carbide. This structure is typical of properly quenched high speed steel and will be called polyhedral.

The polyhedral structure, smaller volume change, constancy of hardness, and more rapid loss in magnetization with quenching temperature in this range are all suggestive of austenitization, though the polyhedral

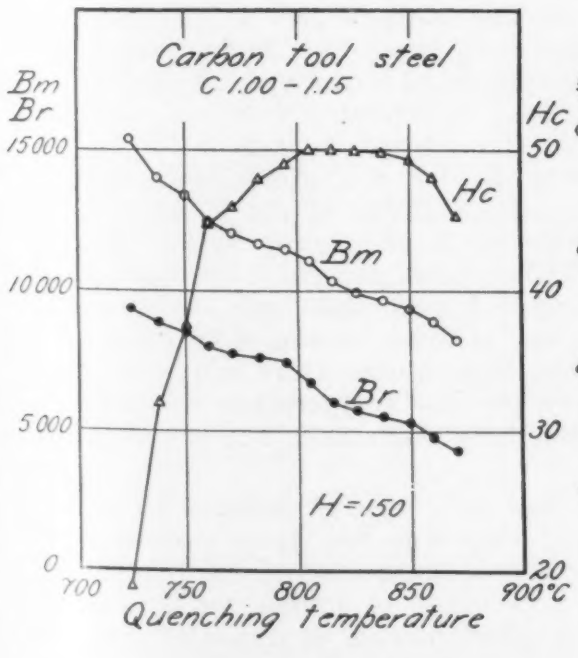


Fig. 6—(left) Relation of quenching temperature to coercive force, maximum induction, and residual reduction of carbon tool steel. (Gebert)

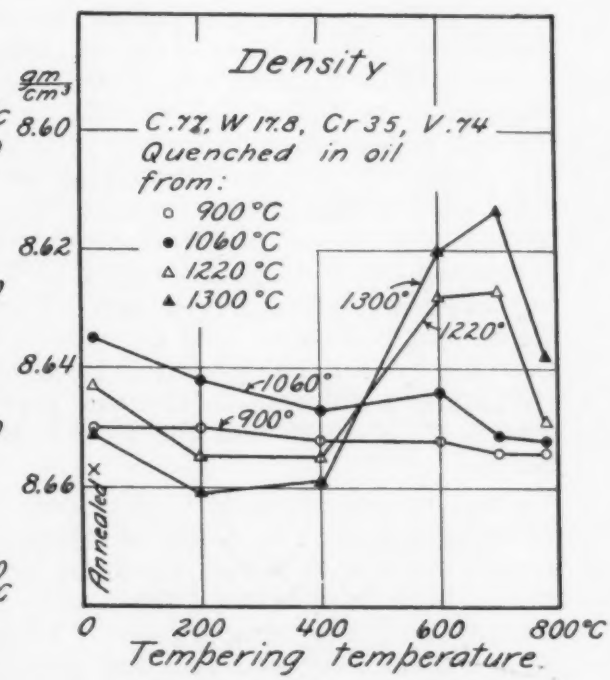
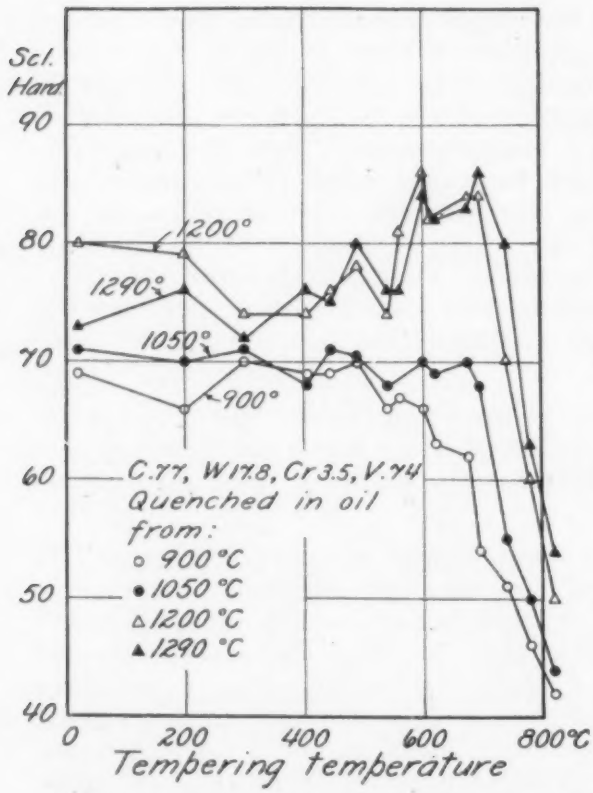


Fig. 7—(right) Change in density of steel A with tempering temperature.



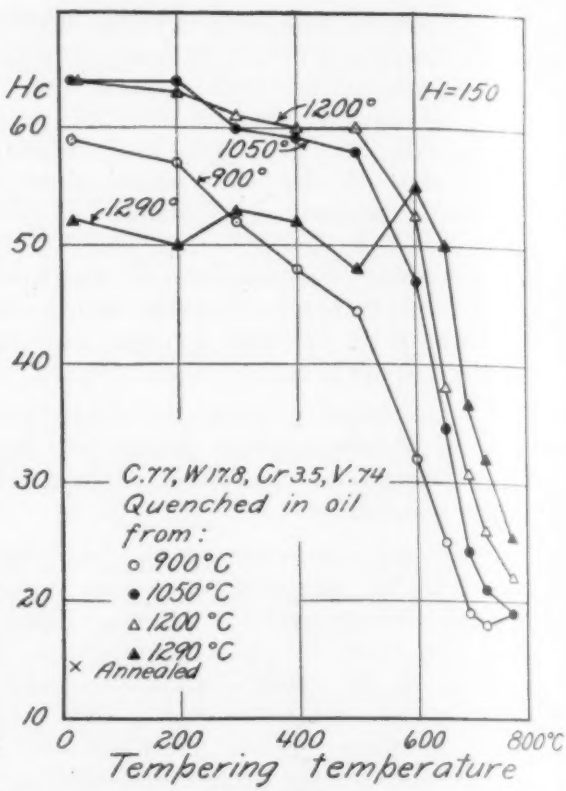


Fig. 8—(left) Change in scleroscope hardness of steel *A* with tempering temperature. **Fig. 9**—(right) Change in coercive force of steel *A* with tempering temperature.

structure is not necessarily proof of it. It is seen by extrapolation of the magnetic properties that zero magnetization, and hence complete austenitization, would be attained for a quenching of about 1450 degrees Cent. if this temperature could be reached without fusion. That partial austenitization has occurred on quenching from the high temperature range is shown, however, by the changes in physical properties on cooling below ordinary temperatures. This treatment, if carried to a low enough temperature, completes the A_3 transformation with a corresponding change in physical properties, direct evidence of previous austenitization. The effect on the magnetic properties of immersion in liquid air is shown in Fig. 4. The volume also increases on cooling below ordinary temperatures, a drop in density of 0.059 grams per cubic centimeter being observed when a specimen of steel *A* quenched from 1300 degrees Cent., was cooled to —45 degrees Cent. It must be concluded, therefore, that the specimens quenched from the high temperature range are constitutionally different from those given the low temperature treatment in that in the former case the steel is partially austenitic, but is not in the latter.

This characteristic of high speed steel may appear peculiar to it, but on reference to the work of Maurer[7] one will find that more or less partial austenitization is common to simple high carbon steel quenched from a high temperature, the degree depending, of course, on the carbon content and the temperature. This phenomenon is revealed by the change in density and in other physical properties on immersion of the steel in liquld air.

A further analogy between carbon and high speed steel may be seen

[7]Maurer, Revue de Metallurgie, 5, page 711; 1908.

by comparison of the effect of the quenching temperature on the magnetic properties of high speed steel, Fig. 4, with the effect of the same variable on those of a carbon steel, Fig. 6. The data for the carbon steel were taken from Gebert.[8] The similarity of these two figures is striking when the lack of any similarity in miscrostructure is considered.

The most interesting feature of the tempering of high speed steel is the socalled "secondary hardening," which is revealed as an increase in hardness over the original or a previous minimum of certain high speed steels given the high temperature treatment and tempered in the neighborhood of 600 degrees Cent. This, at first sight and in view of its absence in the usual carbon tool steels, is often considered a mysterious phenomenon. However, when the original condition of partial austenitization resulting from the high temperature treatment is considered, the phenomenon appears quite natural.

The effect of increasing the quenching temperature is to increase the amount of dissolved carbide which lowers Ar″ (Ar_3—$_2$ of martensitic steels, which is long and continuous for high alloy contents) progressively, until, for a quenching temperature of about 1100 degrees Cent., its end reaches room temperature. Any further increment of the quenching temperature—that is, quenching from the high temperature treatment range—will cause the end of Ar″ to fall below ordinary temperatures, with the result of partial austenitization already noted. This phenomenon is analogous to the lowering of Ar_3 in iron-nickel alloys by increasing the

[8]Gebert, Proceedings, American Society for Testing Materials, 19, Part II, page 117; 1919.

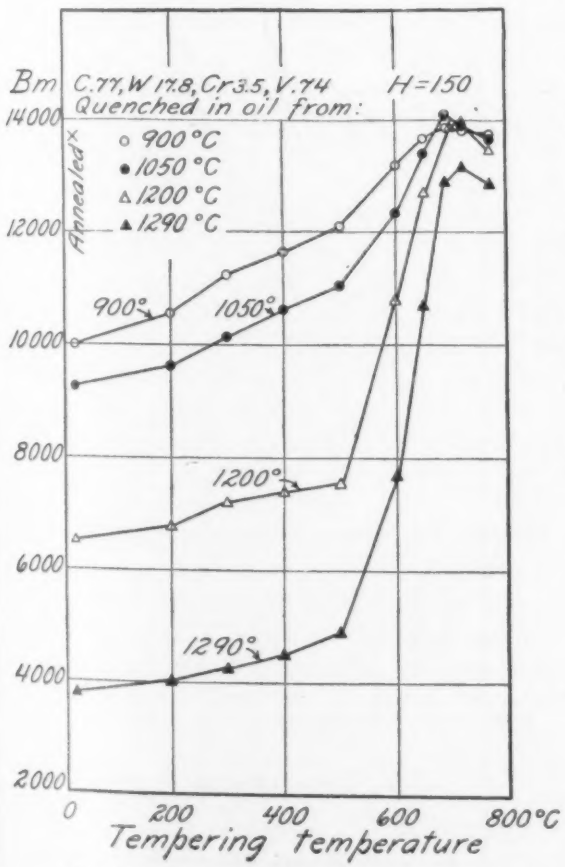


Fig. 10—(left) Change in maximum induction of steel *A* with tempering temperature.

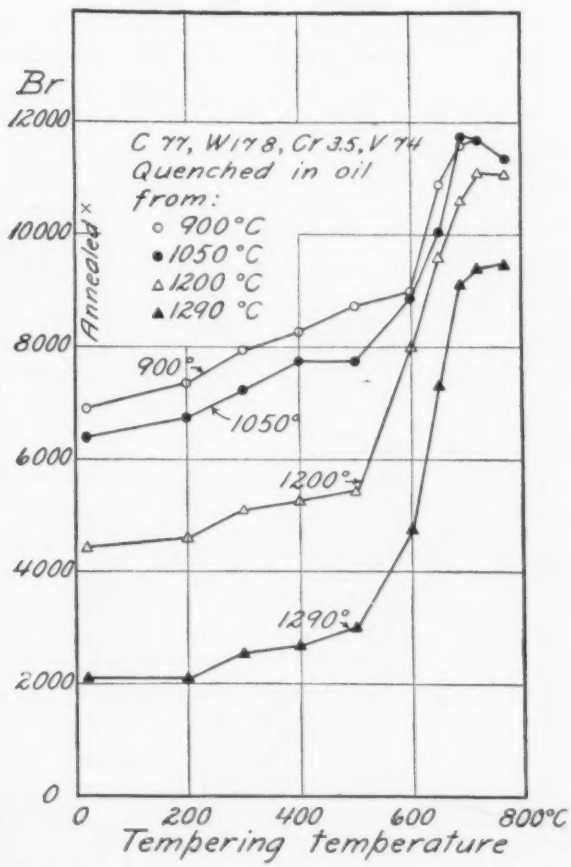


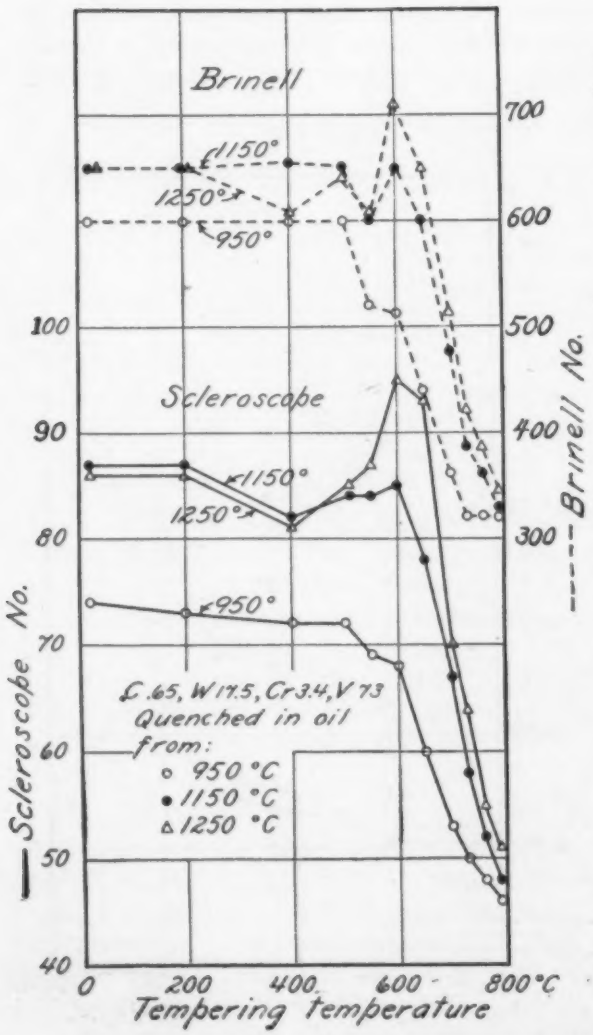
Fig. 11—(right) Change in residual induction of steel *A* with tempering temperature.

nickel content, the essential difference being that in the preceding case the composition of the matrix can be changed by tempering, but it can not be so changed in the latter.

From the foregoing analysis it is evident that on tempering the partially austenitic, and consequently somewhat softened steel, the dissolved carbide of the matrix will be gradually precipitated until a stage is reached at which Ar″ is no longer stable for the then existing temperature and composition of the matrix. Ar″ will then complete itself as in the case of the austenitic carbon steel discussed in another paper.[9] The consummation of Ar″ implies martensitization, and consequently an increase in hardness, which the physical property and microstructure data verify.

The effect of tempering temperature on the physical properties of steel *A* quenched from several temperatures is shown in Fig. 7, density; Fig. 8, scleroscope hardness; Fig. 9, coercive force; Fig. 10, maximum induction; and Fig. 11, residual induction. The reciprocals of the density values have been plotted to show more clearly their relation to the hardness values. In Fig. 12 are given brinell and scleroscope curves for steel *B*.

[9]See footnote 1.



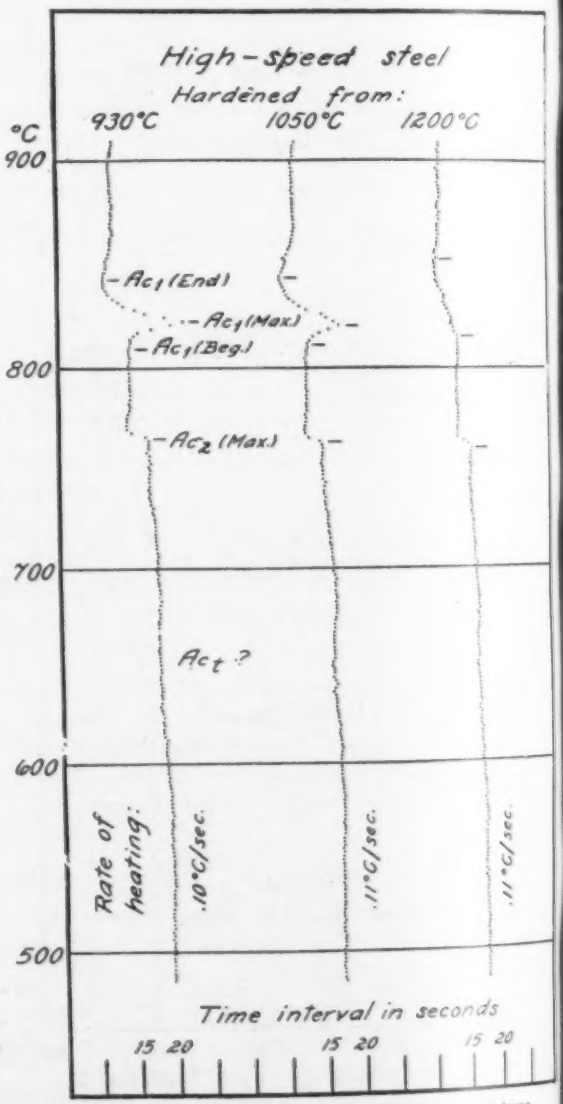


Fig. 12—(left) Change in Brinell and scleroscope hardness of steel *B* with tempering temperature.
Fig. 13—(right) Heating curves of quenched specimens, steel *A*.

The hardness curves, Figs. 8 and 12, show the phenomenon of secondary hardening only when the steel was quenched from the high temperature range, above 1100 degrees Cent., thereby confirming its relation to partial austenitization noted only in specimens quenched in the same temperature range. The curves representing the results of the low temperature treatment as similar to those of carbon steels with the exception that tempering occurs at a much higher temperature, thus shortening the temperature range over which troostite is stable, with the result that the change from martensite to sorbite, or complete softening, is quite abrupt. The density change is very small, indicating a slight solubility of the carbide in the low temperature treatment range.

Of chief interest is the tempering of specimens given the high temperature—that is, the most efficient—hardening treatment. The density curves, Fig. 7, show very markedly a peak between 600 and 700 degrees Cent., which is parallel to the hardness curves and corresponds to a large increase in volume. This is direct evidence of martensitization, and the magnetic properties offer further confirmation. The increase in maximum and residual induction, Figs. 10 and 11, normally indicative of softening, accompanies the rise in hardness in the secondary range.

Secondary hardening, as defined here, has been looked upon as a feature peculiar to high speed steel. The work of Maurer, however, shows that hypereutectoid carbon steels quenched from the neighborhood of A_{cem} exhibit the same phenomenon as revealed by density measurements, to a degree dependent on the amount of carbide retained in solution. The only difference between the high carbon and the high speed steel is that the peak comes at a much lower temperature in the former case, and the tempering below the peak is naturally more evident. The increase in intensity of the peak with an increasing degree of austenitization is evidence of a general relation between secondary hardening and partial austenitization.

The conclusions arrived at from an examination of the physical changes on tempering as related to the phenomenon of secondary hardening should be capable of verification by observation of the accompanying microstructural changes. Micrographs of specimens of steel *A* quenched from 900, 1050, 1200, and 1290 degrees Cent. are given in Figs. 14, 15, 16 and 17 respectively, as tempered at several temperatures. The first two figures show the structure resulting from a low temperature treatment and the second two from a high one.

Micrographs *a* and *b* of Figs. 14 and 15, low temperature treatment, show an immature martensitic pattern resulting from tempering at 300 and 400 degrees Cent. At 600 degrees Cent., the structure is apparently that of homogeneous troostite, and at 700 degrees Cent. the decomposition of troostite into sorbite is well advanced. It may be noted on referring to the relations between physical properties and miscrostructure of carbon steels[10] that the same general relations exist for the high speed steel quenched from the low temperature range.

The micrographs of specimens given the high temperature treatment, Figs. 16 and 17, show a rather astonishing phenomenon. Tempered at 200 and 400 degrees Cent., micrographs *a* and *b* a well developed, needle-like pattern, suggestive of martensite, is produced. When it is considered that the steel is still partially austenitic, the propriety of calling this constituent martensite is questionable. When tempered at 600 de-

[10]See footnote 1.

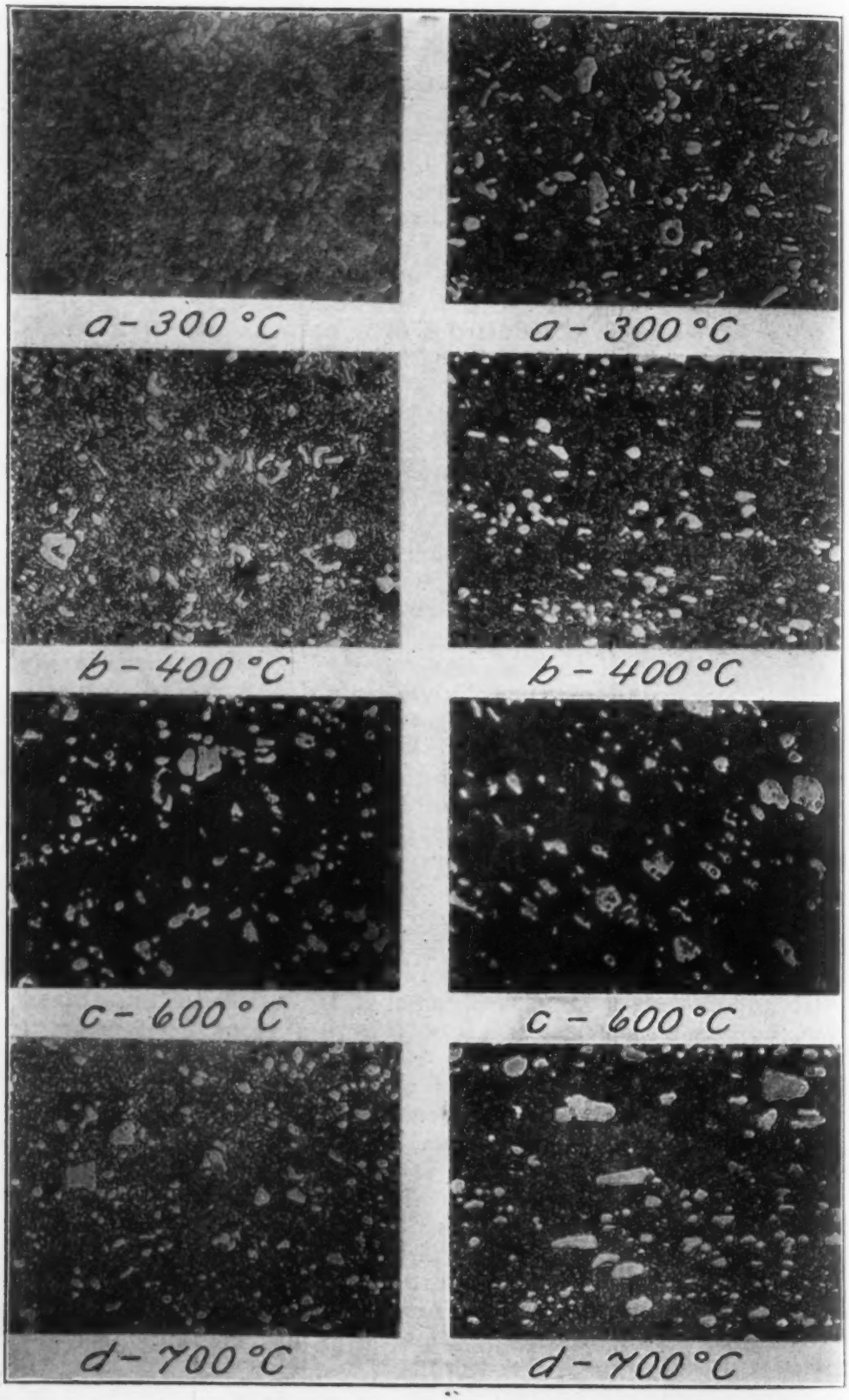


Fig. 14—(left) Microstructure of steel *A* quenched in oil from 900 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 300 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent. Fig. 15—(right) Microstructure of steel *A* quenched in oil from 1050 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 300 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent.

grees Cent., micrograph *c*, where secondary hardening first appears, a definite martensitic pattern quite similar to that of martensitic carbon tool steel is developed. For a tempering temperature of 700 degrees Cent., micrograph *d*, the structure is that of the first stages of troostite, of tempering, and for a temperature of 800 degrees Cent., Fig. *a*, it is that of sorbite, the structure here being practically identical for all quenching temperatures and similar to that of the annealed steel.

The microscopic evidence is positive and confirmatory of the physical, namely, that the constituent accompanying the appearance of secondary hardening is martensite. The nomenclature of the patterns developed at 200 and 400 degrees Cent., however, must await a more precise definition of the constituent martensite.

From the relations pointed out in a previous paper[10] between the heat evolution, Ac_t, observed on heating hardened carbon steels and the accompanying changes in physical properties and microstructure, it might be supposed that similar relations exist for the high speed steel. Heating curves were, therefore taken of steel *A*, Fig. 13, quenched from three temperatures. The inverse rate method was used, and the thermal characteristics noted on the curves are given in the table below. There is evidence of a slight heat evolution, Ac_t between 600 and 680 degrees Cent., but it is not sufficiently intense to allow of any positive conclusions. This is probably due to the rather limited solubility of the carbide in the matrix and the sluggishness of its precipitation, the rapid heating rate required by thermal analysis allowing insufficient time for its consummation. Note the loss in intensity of Ac_1 with increased quenching temperature. The transformation characteristics of steel *A* on heating following quenching are as follows:

Quenching temperature	Rate of heating	Ac_2 maximum	Ac_1		
			Beginning	Maximum	End
Degrees Cent.	Degrees Cent. per second	Degrees Cent.	Degrees Cent.	Degrees Cent.	Degrees Cent.
930	0.10	765	810	823	843
1050	0.11	763	811	821	844
1200	0.11	760	...	815	852

These curves are in substantial agreement with Carpenter's[11] observations from differential curves on a tungsten chromium high speed steel, with the exception that he does not recognize the transformation Ac_2, this due to the lack of its characteristic features in differential curves.

Inasmuch as the high grade high speed steels have much in common in spite of the wide range of compositions represented, it is permissible to generalize somewhat from the observations made on the familiar type of high speed steel used here. It must be remembered, however, that the degree of secondary hardening is a function of the carbon and chromium content and also, probably to a less degree, of the other alloying elements.

The rationale of the high temperature treatment becomes evident from an analysis of the physical characteristics. By defining red hardness as the resistance to softening by tempering, one may see from the hardness versus tempering-temperature curves that the red hardness increases slightly with quenching temperature. This is evidently one patent reason

[10] See footnote 1.
[11] See footnote 3.

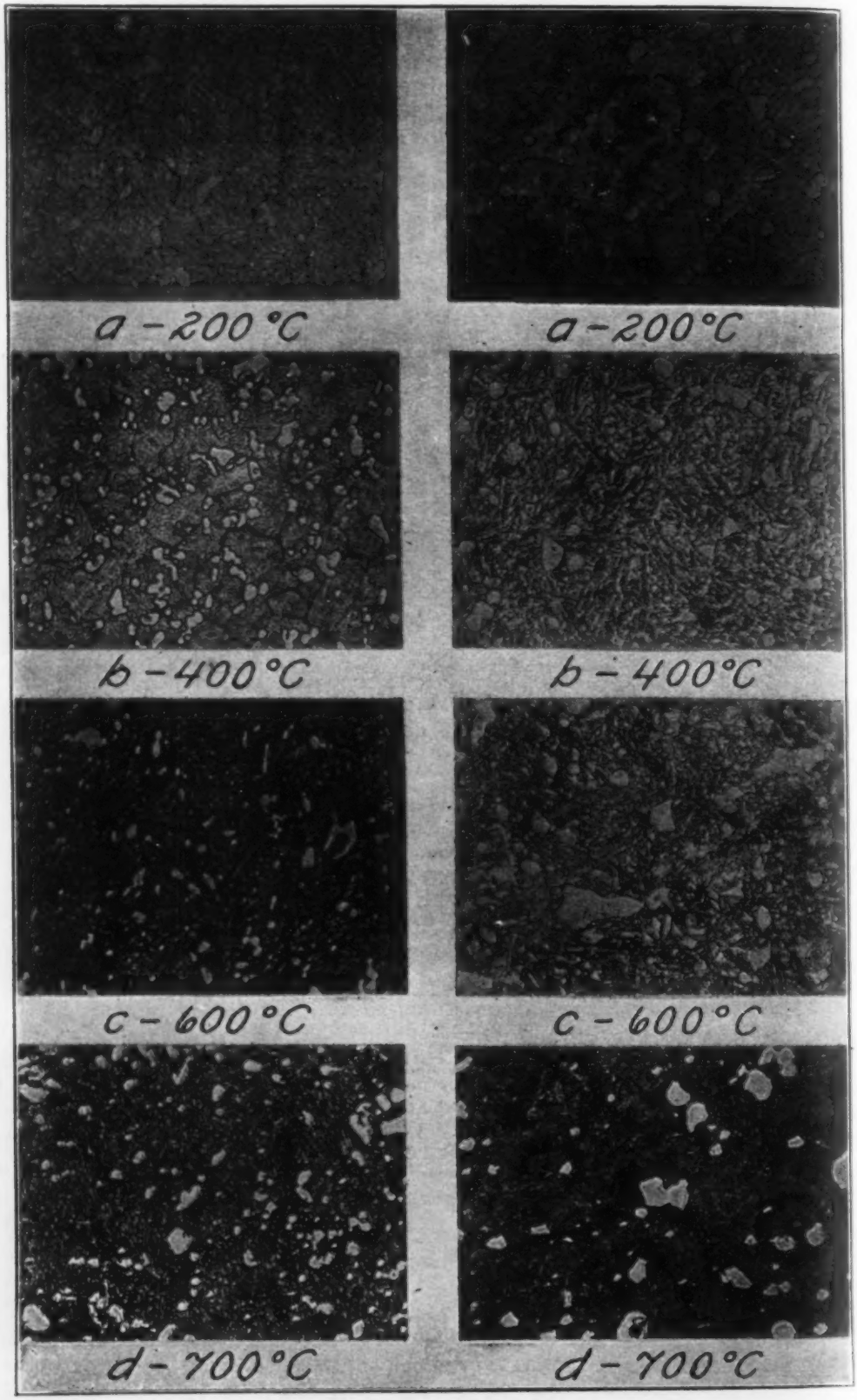


Fig. 16—(left) Microstructure of steel *A* quenched in oil from 1200 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 200 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent. Fig. 17—(right) Microstructure of steel *A* quenched in oil from 1290 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 200 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent.

for a high quenching temperature. The initial hardness also increases with the quenching temperature, at least in the low temperature range, and this is a further highly desirable characteristic. With the increase in hardness there is a corresponding increase in volume and consequently in volume change on quenching, conditions which favor the formation of cracks. If, however, the steel be hardened from the high temperature range with partial austenitization, the density change is not increased, and the steel, even if not less hard, is less brittle, thus counteracting its tendency to crack and furnishing the most satisfactory combination of properties.

There has been much discussion as to the value of tempering for maximum hardness or secondary hardening. This is evidently largely a mat-

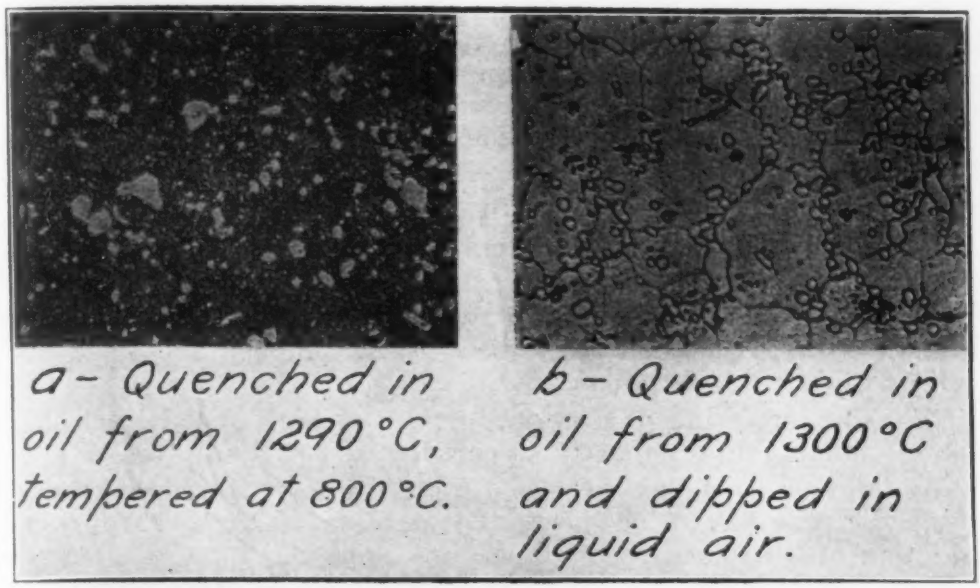


Fig. 18—Microstructure of steel *A*. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, quenched in oil from 1290 degrees Cent. and tempered at 800 degrees Cent.; *b*, quenched in oil from 1300 degrees Cent. and dipped in liquid air.

ter of composition for a given treatment, as this factor determines the degree of secondary hardening possible. For a steel showing this phenomenon definitely, the increased hardness, if not accompanied by greater brittleness, which hardly occurs in this case, is certainly of value in a tool, no matter what its use. The increase in volume on tempering for secondary hardening deserves some consideration on selecting a treatment for a given tool. It is apparent that heating in service may change the dimensions of an untempered tool to a troublesome degree. Tempering for secondary hardening is, therefore, of general advantage, but it is certainly not of any value to temper at a lower temperature where these advantages do not accrue and where practically the same degree of effort is expended.

The comparatively long temperature range, about 100 degrees Cent., in which secondary hardening may be obtained suggests that a considerable constitutional difference between the product of the high and the low end of the range may exist, probably corresponding respectively to martensite and troostite. This being the case, it should be of interest to

determine whether the low or high temperatures giving the same degree of hardness will give the better cutting results.

The sharpness of the changes in the magnetic properties and in the density would indicate that these properties furnish a valuable test for determining without destruction whether or not a tool has been properly tempered. Of the hardness tests, the brinell is of little value on account of the very high degree of hardness involved. The scleroscope, however, if properly handled, is quite useful, although it is not as sensitive as the brinell to the advancement of the change from martensite to troostite. On the whole the physical properties determined for a hardened steel, while of course not furnishing a direct criterion of its cutting efficiency, do offer a valuable indication of the constitution of a given steel, and this is the principal value of most physical and mechanical tests.

Attention is called to the importance of fundamental research applied to high speed steel and the value of physical tests for this purpose.

The effect of heat treatment on the density, hardness, microstructure, magnetic properties, and thermal characteristics of a standard brand of high speed steel was determined. The interpretation of these data permits the following conclusions:

1. A high speed steel susceptible to secondary hardening is partially austenitic when quenched from a temperature high enough to produce this phenomenon.

2. The microstructure of steels hardened and tempered above 200 degrees Cent. is similar to that of carbon steels, although the same nomenclature in certain cases is not permissible.

3. The behavior of the physical properties of high speed steel on heat treatment is analogous to that of hypereutectoid carbon steel.

4. The following reasons are given for the use of the high heat treatment: (a) Increase of red hardness; (b) increase of initial hardness; and (c) reduction of brittleness.

5. High speed steel should preferably be tempered for secondary hardness.

SELECTION OF HIGH SPEED STEEL FOR TOOLS

By Henry Traphagen*

(A Paper Presented at the Philadelphia Convention)

A most perplexing problem confronting the tool manufacturer today is a steady supply of physically uniform high speed steel. Plenty of high speed steel on the market is chemically uniform, but it is a man's size job to cull out the physically defective material.

Without sound steel, the fabrication of high grade tools is impossible, for after all, no tool is any better or stronger than its weakest point. The most careful machine work, the best of the hardener's art, cannot save a tool from the scrap barrel if the steel is defective. It is true that careless or incompetent heat treatment will ruin the best of steel, but by no stretch of the imagination can we conceive of a tool giving satisfaction, if the raw material is physically unsound.

Judging from the mass of literature floating about the country, one would think that a steady supply of sound high speed steel is easily obtained, but after examining ton after ton from practically every important mill in the business, the writer is forced to the conclusion that consistently uniform high speed steel does not exist. The only recourse left to the careful conscientious manufacturer of tools, is to test every single bar of raw stock that is received.

Perhaps you will ask what do we mean by uniform high speed steel. We mean steel that is free from pipes, seams, cracks, segregated carbides, decarbonization and fiber—steel that will harden quickly and uniformly with a smooth velvety grain which is almost amorphous. That a steel should harden is not enough; the grain must be smooth and even, the steel must be tough as well as hard. An even grain will not compensate for a pipe down the center; hardness combined with a woody structure, means brittleness; and the finest grain in the world is absolutely nullified if that characteristic shiny crystalline ring of decarbonization is present. Will chemical analysis detect such defects? Will the scleroscope or Brinell machine reveal the presence of internal cracks or fiber? Show the author any test short of destruction by fracture, that will safeguard the consumer against such defects, and he will adopt such a test immediately and see that proper credit is promptly and fully given.

From the very beginning of its existence, the company for which the author is metallurgist, determined that nothing but physically sound steel should ever enter its tools. Every method of testing that could be suggested was tried and some of these experiences may be of interest.

For a long time every shipment was properly sampled and carefully analyzed. The author has in his office records covering over a thousand consecutive samples. In practically every instance the analysis was found to be satisfactory. Only two samples did not check up to the standard specifications. Such performance is a remarkable tribute to the efficiency of our steel works laboratories, but it is sad commentary on the insufficiency of chemical analysis, when it is stated that about 30 per cent of all steel received was rejected for physical reasons.

Hardness testing by the scleroscope and Brinell machine on both annealed and hardened samples showed nothing, for positively no connection was found between hardness and machine shop performance, barring of

*Metallurgist, Fast Feed Drill & Tool Corp., Toledo, Ohio.

course, an occasional specimen that was underheated and very soft and which would easily bend.

It seemed that ordinary routine testing would not solve the problem, so scientific literature was ransacked in the hope that some simple test might be found that would detect internal defects. A wonderful assortment of physical test reports, photomicrographs, temperature curves, Brinell tests, critical point controversies, were gathered, only to lead to the conclusion that the steel industry was suffering from a bad attack of scientific indigestion.

Psychologists tell us that doing the obvious thing is the most difficult feat for humans to accomplish. If a thing is simple and obvious we generally overlook it. You know the old adage about judging the pudding by eating it. Why not test steel by hardening it? That is exactly what is being done today with every single bar of high speed steel that enters the author's plant. The procedure is as follows: As soon as steel enters the receiving room it is placed upon a special rack, and it does not leave that rack until it is either accepted or shipped back to the mill. A piece from each bar is hardened by preheating slowly and thoroughly at 1650 degrees Fahr., and then heating quickly in a furnace maintained at 2400 degrees Fahr., after which the piece is quenched in oil until cool. The hardened piece is then broken transversely and longitudinally and the fracture examined with a small low-power pocket lens.

If the piece breaks easily we are suspicious and look for either fiber or excessive carbides, and one or the other generally is found in brittle steel. If the steel is decarbonized the shiny crystalline ring is so apparent that it is found in a glance. Much of it is found. A pipe, no matter how small, may be uncertain in the transverse fracture, but the longitudinal break quickly shows it up. If the tungsten content is low, the structure generally is found to be coarse and crystalline when hardened at the high heat of 2400 degrees Fahr. Woody fibrous structures are very common, but always show up in the longitudinal fracture; in the transverse break, however, it is often masked. Rejections are never made on a single test. If the sample from one end of the bar is defective, one is cut from the other end, and if that fails the bar often is cut in two and the middle tested. In order to eliminate the possibility of incorrect heat treatment, at least two, often three men harden the samples on different days, without knowing where the sample comes from. It is possible for an error to creep in, in one hardening, but the average results of different men on different days where the defect appears again and again is positive proof that the steel is faulty. The test must be fair and no amount of retesting is spared if the slightest doubt exists. But in spite of such repeated and careful testing over 30 per cent of the steel goes back.

Is a clean, smooth uniform structure any index of a tool's value? To answer this question, dozens of drills were made up from what appeared to be excellent steel. These drills were tested not in the laboratory, but in a heavy-duty drill press. They were jammed through foot after foot of heat treated forgings, very little lubricant being used. The drills stood up. Then they were taken out of the presses, bounced on a concrete floor time and again to test for toughness, placed again in the drill press and the whole performance repeated. These tests coupled with many official competitive tests have proved many times the value of fracture tests in selecting high speed steel for drills and other tools.

Any criticism or suggestion to be of any value must be constructive. The object of this article is to place before the high speed industry, the necessity of rational physical testing. It is expensive and unpleasant to have to reject bar after bar of steel. The author gives assurance that the rejection of steel costs the consumer more than it does the manufacturer. If the fracture test should become more general it would not be long before experimental heat treating laboratories would be in every steel warehouse, and hardening would soon play as important a part in the testing of steel as chemical analysis now does.

In presenting this article, the author is not under the delusion that fracture testing is anything new or novel, but he does know that this simple exhaustive method of testing has not been given the consideration it deserves.

DISCUSSION OF MR. TRAPHAGEN'S PAPER

MR. D'ARCAMBAL: Have you ever run any tests on drills, drawing some to a temperature of 500 degrees Fahr. or thereabout, and also to 1100 degrees on tough steel?

MR. TRAPHAGEN: That is a case in which there are certain forms of very tough portions and toughness would have to be sacrificed for hardness. In that event we would use a full martensitic structure, but we know that the tool is liable to break, not from the hardness point, but from the action of wobbling or something of that sort.

MR. D'ARCAMBAL: We took a ¾-inch round bar of high speed steel and cut it in lengths of 7 inches. It was then turned down to 11/16 inches and the specimens quenched to 2300 degrees Fahr. in the open furnace. Half of these were drawn at 450 degrees and the other half to 1100 degrees. They were then put under the transverse machine, those drawn to 450 degrees broke at 4200 pounds while those drawn to 1100 degrees broke at 11,000 pounds at two and one-half times bending. I should think that would denote greater toughness on the 1100-degree draw. Those drawn to 450 degrees were brought up in oil and held 5 minutes; those at 1100 degrees were held about 10 minutes. I think that is one point that is not understood. I think drawing at 1100 degrees you get the greatest benefits by holding to 15 or 20 minutes.

MR. TRAPHAGEN: But has not its life started on the downward path?

MR. D'ARCAMBAL: All the tests were taken from the same bar of steel. It was regular high speed steel, 0.16 or 0.17 per cent carbon, 18.0 per cent tungsten, and 3.5 per cent chromium. It was etched and microscopical examinations made of it. This was not in the form of a drill.

MR. TRAPHAGEN: Did you break the whole thing wide open?

MR. D'ARCAMBAL: We supported it between V blocks and took the other V and broke it down. But on the cutter tests one of the factors is that of toughness; in tearing through the steel you have to have a pretty tough proposition. That is where the 1100 degree draw did two to four times the work that the 450 degree draw did.

MR. TRAPHAGEN: That may be, but we have found that our drills gave the best service when they were about 78 scleroscope, which is rather low. Somewhere around 85, which I think is also filed soft, does not stand up as well.

MR. D'ARCAMBAL: At a meeting a few minutes ago one man brought out that point. He was using the drills in tough metal, as good

as they could receive from the manufacturer, and it would not go through the tough steel. They drew them all to 1050 degrees Fahr. and got good results.

MR. TRAPHAGEN: We can do the same thing on the heat treated nickel-chrome forgings, but we have found somehow or other that then we have more trouble with the men snapping them off. They cut alright, however.

MR. D'ARCAMBAL: What temperature do you think the drill gets to in the usual running?

MR. TRAPHAGEN: I don't imagine it gets more than 400 or 500 degrees Fahr. at the maximum.

MR. D'ARCAMBAL: You said a drill would harden itself in service?

MR. TRAPHAGEN: It is a localized hardening, I think.

MR. STAGG: I can't help but rise in defense of the poor chemist and the hard working metallographist and the mere metallurgist. We know that material can be inspected fairly well by a simple test, and the usual tests that have been outlined, but in order to get a truer percentage of rejections, I am quite sure were it not for the activities of the poor chemist and the hard working metallographist and the mere metallurgists, the rejections instead of being 25 per cent would be perhaps somewhere nearer 75 per cent. One point in discussion; I think Mr. Traphagen mentioned the fact that he was going to not quite a martensitic structure and then later he mentioned the fact that he was drawing at 1100 degrees Fahr.

MR. TRAPHAGEN: The point is the matter of time. We leave it in there only about 30 seconds, just enough to start it going. You could easily get the martensitic structure if you leave it there long enough. We just start it going. One more point in that connection; I made the statement that the chemist and the laboratory are absoluely essential for the production of steel, but I am talking about the consumer of steel analyzing that stuff and applying the microscope to find out its suitability for his product. In other words, he must get his product practically made and then find out the condition of that steel as a whole, not as a part. Your point is well taken. A steelworker couldn't exist without a laboratory, but there are too many manufacturers spending a lot of money on equipment and chemists and fellows of that sort when they ought to have a good hardener. I am willing at any time to pay full tribute to what the metallurgists and chemists have done for the steel industry, but the trouble is that there is no proper backing up of them by the other fellows in the right way.

MR. D'ARCAMBAL: I am not a man of the steel mills, so I am going to stand up for the consumer. In the case of these cutter tests we ran, the No. 7 steel ran only 1.18 per cent vanadium and the fracture was beautiful and it did not show anywhere near the efficiency of the 1.75 per cent vanadium steel.

MR. TRAPHAGEN: In working with a standard product, did you take the pains to fracture that steel in two directions?

MR. D'ARCAMBAL: We didn't.

MR. TRAPHAGEN: Sometimes you will find a most marvelous change. Your transverse section will work beautifully and the longitudinal section will be altogether different.

MR. D'ARCAMBAL: I also believe that 90 per cent of the rejec-

tions in our laboratory are on physical tests, but every once in a while we get a steel with lower carbon and we don't find that out until we make the thing up, or a steel with lower tungsten, and it will give a nice fracture, but it will not give the efficiency.

MR. TRAPHAGEN: We have a laboratory, but we have found that as a rule a low tungsten steel will not stand up. When we get a tool and break it open and find something wrong with the fracture and after we have done that two or three times to be satisfied that the heat treater is off the job, then we start with the microscopes and work backwards. But we do not waste time in useless routine analysis or taking pictures when we can tell immediately by making a fracture. In addition to making a fracture on the lower steels, I grab half a dozen drills and smash them up. Every once in a while we will take a drill outside and try it for 15 or 20 minutes. Now, taking all those tests together and using science to ferret out some of the difficulties, I think we have a good check up.

MR. D'ARCAMBAL: I agree with you that the fracture test has not been developed to the limit of its possibilities.

MR. TRAPHAGEN: It is the test of the steel man almost altogether. He wants to try it on everything.

MR. D'ARCAMBAL: When you come to carbon tool steel, you get a carbon tool steel that is annealed from the mill and it will show you a crystalline structure, but your fracture will not show you that.

MR. TRAPHAGEN: When you harden that piece of steel, break it open transversely where you think it is hardened down so far you cannot break it any further. I have broken 17 bars of one of the best known steels made just recently, and I found one good one out of the 17, and yet they were beautiful on the surface. But they only were good down a little distance. They run from temperatures of 1425 up to 1700 degrees Fahr. Then I increased the time in the lathe from 2 minutes to 10 and combined the long time and the long immersion and couldn't get any change.

News of the Chapters

NEW CHAPTER ESTABLISHED IN WORCESTER

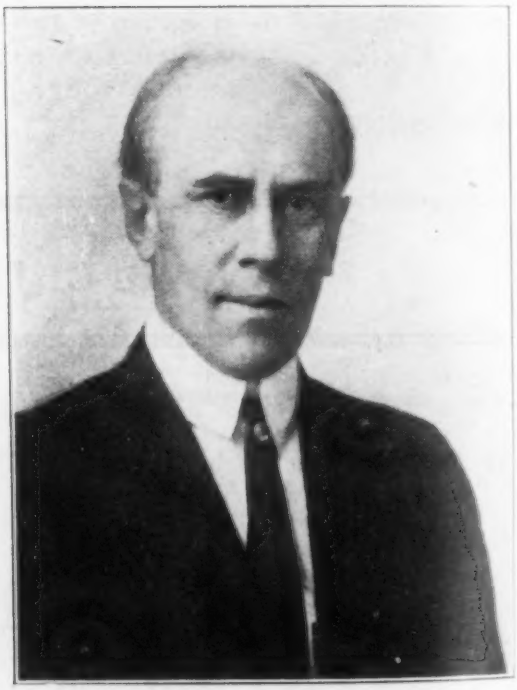
The organization meeting of the Worcester chapter of the American Society for Steel Treating was held on April 27 with about 65 men in attendance. The principal speakers of the evening were: John F. Tinsley, vice president and general manager of the Crompton & Knowles Loom Works who gave a very interesting talk on the "Advantages of Metallurgical Study"; and Alvin T. Simonds, president of the Simonds Mfg. Co., spoke with reference to the advantages of close co-operation between producers and fabricators of steel.

Other speakers were: R. C. Helm, metallurgist of the American Steel & Wire Co.; Leslie C. Heath of the Simonds Mfg. Co.; and John

VICTOR HILLMAN
Elected Chairman of New Worcester Chapter

J. E. ROGERS
Elected Secretary-Treasurer of New Worcester Chapter

H. C. KNERR
Elected Vice Chairman of Philadelphia Chapter



ALEXIS CASWELL
Re-elected Secretary-Treasurer of North West Chapter

C. Spence, superintendent of the Norton Co., machine division, who gave their views on the advantages of the Society.

Election of officers resulted in the following selection: Chairman, Victor E. Hillman, metallurgist of the Crompton & Knowles Loom Works, Worcester, Mass.; secretary-treasurer, J. E. Rogers, secretary, A. Hankey & Sons Co., Rochdale, Mass. Members of executive committee: Thure Larson, mechanical engineer, the Norton Co., Worcester, Mass.; Paul A. Porter, Worcester, Mass.; Chester M. Inman, Pratt & Inman, Worcester, Mass.

Chairman Hillman stated the aims and purposes of the Worcester chapter as follows:

"Tonight marks the inception of the Worcester chapter of the American Society for Steel Treating. The time is come when Worcester and her environs feel that they can support an offspring of the parent body. The National Organization, of which we become a part, resulted from the fusion of two independent societies, each of which were disseminating knowledge pertaining to the metallurgy of iron and steel. The result was that a powerful society sprang into existence, with headquarters in Cleveland, and a membership of 2959.

"America's foremost metallurgists have affiliated themselves with the organization. Fifty-four steel companies are listed as sustaining members. The proceedings of the body are recorded in a monthly publication known as Transactions. Those of you who are familiar with the journal will admit that it is an arsenal of knowledge and that it contains a wealth of ideas.

"Sir Robert A. Hatfield, an English metallurgist, and the inventor of manganese steel, is an honorary member of the national body. As you have probably read in the daily press, he will receive the John Fritz medal in London, June 29. The presentation is of particular interest to Worcester people, because Dr. Ira N. Hollis, President of the Worcester Polytechnic Institute will convey America's greetings.

"Twenty-eight chapters are located in various industrial centers of the country. Each is glowing with youth, vigor, and vitality, and our birth tonight will place a formidable rival in their midst. The purpose of creating a local chapter is to bring the executive, the laboratory technician, the foreman, and the mill operator into closer relationship. In brief, we propose to fuse apprenticeship, practical experience, and technical knowledge into one homogeneous mass. Papers will be presented from time to time, after which a general discussion dealing with various phases of the subject will be in order.

"Our chapter will also feature what is known as a 'question box'; that is, every one who attends the meeting of the society is privileged to submit his questions in writing to the presiding officer. The chairman will make an effort to have them answered. For instance, you may be experiencing trouble in machining a certain grade of steel. You are asking a remedy for overcoming the difficulty. There will always be men in attendance who are qualified to suggest ways and means for obtaining relief. Or again, you may be sustaining enormous losses due to the fact that you are violating certain fundamental metallurgical laws. If your trouble is brought up for open discussion, I feel confident that everyone will contribute his share of experience toward the solution of your problem.

"The chapter has a message to extend to all those who are inter-

ested in steel and its heat treatment. If we avail ourselves of the opportunity to mingle with one another, we will absorb and impart ideas in accordance with the adage, 'a fair exchange is no robbery'. If we are to pass through the channels of progress, we must rub elbows with one another. One man's experience alone is not worth a continental, and any one who professes to be self-satisfied with his knowledge, is either a fool or a knave.

"Our nation hold a pre-eminent position as being the largest iron and steel producing country in the world but unfortunately we have not contributed our share to the advancement of the art. Professor Sauveur of Harvard sounded the keynote of our apathy, in Philadelphia last September when he viewed the basic metallurgical inventions in retrospect.

"Even though we make more pig iron, coke, open-hearth steel, wrought iron, electric steel, ferroalloys, and malleable iron than any other country in the world, the basic inventions thereof sprang from foreign shores. The blast furnace was neither developed nor invented in the United States. Coke owes its origin to an Englishman by the name of Abraham Darby. The utilization of blast furnace gases is credited to Aubertot of France: Open-hearth and bessemer steel to Emile Martin and Sir Henry Bessemer of England; electric steel to the French metallurgist Heroult; wrought iron to Henry Cort of England, and malleable iron to the French chemist Reaumur.

"But notwithstanding, American genius is awake to the situation, and she found a niche in the metallurgical hall of fame when Taylor and White of the Bethlehem Steel Co. announced their discovery of high speed steel. I have cited these illustrations in passing, merely to stimulate interest in that fascinating subject, iron and steel".

The second meeting of the Worcester chapter was held on May 19 in the rooms of the New England Metal Trades Association, and was addressed by S. C. Spalding, metallurgist of Halcomb Steel Co., who delivered a very interesting and instructive paper. Eighty-five were in attendance.

BRIDGEPORT CHAPTER

The annual meeting of the Bridgeport chapter was held in the Upper Gymnasium, of the Y. M. C. A. building, on May 10. The meeting was called to order at 7:50 P. M. by Chairman Rodney, when the evening program was carried out. A lecture was given by G. A. Richardson, of the Midvale Steel and Ordnance Co., entitled "The Process of Steel Manufacture" and was illustrated by moving pictures. Communication of "Congratulations" from the national secretary, W. H. Eiseman, was read. An enjoyable evening was spent by the 67 members present.

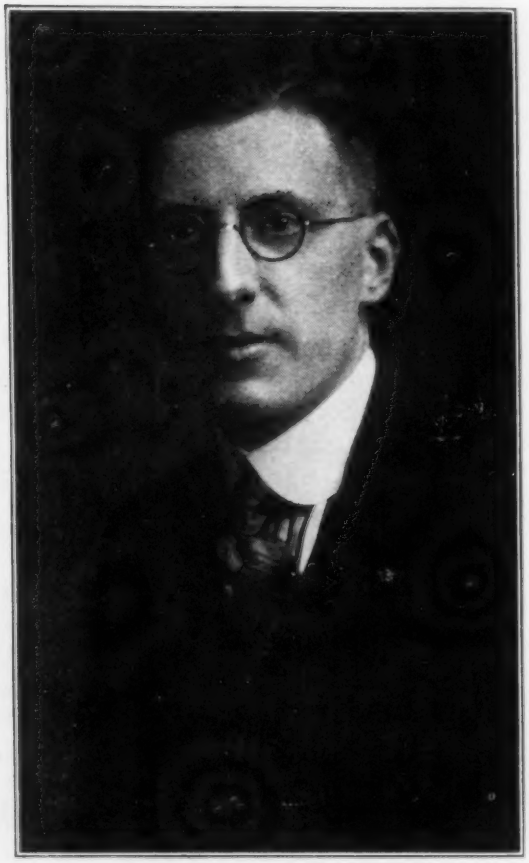
The following officers for the ensuing year were elected: Chairman, Harold T. Dow, superintendent, Spring Perch Co., Stratford, Conn.; vice chairman, Herold Fish, treasurer, Ready Tool Co., Bridgeport, Conn.; secretary-treasurer, C. F. Schmelz, superintendent, Curtis & Curtis, Bridgeport.

Executive Committee: A. G. Baldwin, International Silver Co.; J. E. Cooper, Columbia Nut & Bolt Co.; E. B. Crocker, mechanical engineer, Manning, Maxwell & Moore, Inc.; H. T. Leavenworth, manager Bridgeport Testing Lab.; W. S. Lynne, factory manager Bridgeport Metal Goods Mfg. Co.; J. S. Marran, chief inspector, Remington Typewriter Co.

LLOYD K. MARSHALL
Elected Chairman of Rochester Chapter

ARTHUR W. F. GREEN
Elected Chairman of Philadelphia Chapter

JOHN E. HALBING
Re-elected Chairman of Lehigh Valley Chapter



ALBERT P. SPOONER
Re-elected Secretary-Treasurer of Lehigh Valley Chapter

SPRINGFIELD CHAPTER

The May meeting of the Springfield chapter was held in the Chamber of Commerce building, on May 20. S. C. Spaulding, metallurgist of the Halcomb Steel Co., Syracuse, N. Y., gave a very interesting talk on the "Cause of Failure of Steel". The subject was handled in a thoroughly practical manner and dealt with the causes of many perplexing failures

resulting from improper treatment or handling of the steel in the shop.

The following officers have been elected for 1921-22: Chairman, R. J. Allen, metallurgist, Rolls-Royce Co. of America; vice chairman, E. A. Sanford, metallurgist, Hendree Mfg. Co.; secretary-treasurer, E. L. Woods, industrial gas engineer, Springfield Gas Light Co.

SCHENECTADY CHAPTER

The Schenectady chapter leads as far as securing newspaper publicity is concerned, and sets an example toward which the other chapters might well aim. The following report is taken from the Union Star of May 6:

"Nearly 100 members and guests of the Schenectady chapter of the American Society for Steel Treating were present last evening at the Civil Engineering building, Union College, and heard Lieut. Col. A. E. White, national president of the society and director of engineering research at Michigan University, deliver a lecture on "Alloy Steel—Its Rise and Secrets". Lieut. Col. White is a national authority on alloy steel and has investigated the subject very thoroughly, consequently his paper was of much interest to those in attendance.

"Through the courtesy of some of the members of the Union College Radio Club the much-talked of "Baby Carriage" delivered music via wireless, and the concert was greatly enjoyed and exceedingly interesting.

"A guessing contest was also a feature of the evening entertainment and provided considerable amusement. If the winner did not peep—he's a good guesser.

"Officers were elected as follows: Chairman, Carl L. Ipsen, designing engineering, General Electric Co.; vice chairman, E. J. Edwards, engineer of tests, American Locomotive Co.; secretary-treasurer, B. T. Perry, chief chemist, American Locomotive Co.

"Executive Committee: F. P. McKibben, professor of civil engineering, Union College; E. F. Collins, General Electric Co.; R. Topham, General Electric Co.; B. H. Magill, American Locomotive Co. Their term of office is from May, 1921, to May, 1922. Plans are being completed for the June meeting and an interesting program is promised."

ROCHESTER CHAPTER

The annual meeting of the Rochester chapter was held in the Eastman Building, University of Rochester, on Thursday, May 19. Lieut. Col. A. E. White, national president of the Society, presented a paper on the subject "Alloy Steel—Its Rise and Secrets". Lt. Col. White's paper was very favorably received and the discussion following its presentation was participated in by a large number of those in attendance. The national secretary, W. H. Eiseman, spoke of the advances the society had made during the past year and gave information about the coming convention at Indianapolis.

The following officers were elected for the chapter for the year 1921-1922: Chairman, Lloyd K. Marshall, North East Electric Co.; vice chairman, J. J. Desmond, North East Electric Co.; secretary-treasurer, R. C. Schwarz, 421 Arnett boulevard; member-at-large, Wm. H. Chappell, General Railway Signal Co.; member-at-large, W. W. Phillips, Colonial Steel Co.

PITTSBURGH CHAPTER

The Pittsburgh chapter held its regular monthly meeting at the Chatham Hotel on Tuesday, May 17. Due to the illness of the national president, who was to deliver the principal address of the evening, W. S. Bidle, national treasurer, and W. H. Eisenman, national secretary, substituted. The meeting was well attended and although considerable disappointment was experienced because of the inability of Lt. Col. White to be present, those in attendance had a very enjoyable evening.

The officers elected for the coming year were as follows: Chairman, Dr. C. M. Johnson, director research department, Park Works, Crucible Steel Co. of America; vice chairman, Dr. N. B. Hoffman, Colonial Steel Co.; secretary-treasurer, D. W. McDowell, Jones & Laughlin Steel Co.

For Board of Directors: Prof. Frederick Crabtree, professor of metallurgy, Carnegie Institute of Technology; Prof. S. L. Goodale, professor of metallurgy, University of Pittsburgh; T. D. Lynch, Westinghouse Electric & Mfg. Co.; F. C. Eaton, Pittsburgh Steel Wire Co., Monaca, Pa.; W. B. Crowe, Homestead Steel Works, Munhall, Pa.; Frank Garratt, Latrobe Steel Co., Latrobe, Pa.

CHARLESTON CHAPTER

The regular monthly meeting of the Charleston chapter was held in the assembly room of the Charleston Y. M. C. A. Tuesday evening, May 17. After disposal of the usual business, the annual election of officers for the ensuing year was held, resulting as follows: Chairman, W. J. Priestly, Quarters "B", Armour Park, South Charleston, W. Va.; vice chairman, H. Schagrin, 6 White Ave., S. Charleston, W. Va.; secretary-treasurer, W. H. White, Box 296, S. Charleston, W. Va.

Following the brief address of the newly elected chairman, an interesting and lively discussion of the subject "Flakes", their causes and effects, arose. The main feature of the evening's program consisted of an illustrated lecture by G. A. Richardson, Midvale Steel & Ordnance Co., in which the manufacture of steel from the mining of the iron ore to the shipment of the finished steel products was shown.

PROVIDENCE CHAPTER

The May meeting of the Rhode Island chapter was held in the rooms of the Providence Engineering Society on May 25th. Dr. C. M. Johnson, director of research, Park Works, Crucible Steel Co. of America, spoke on "Resistal Steels", which was illustrated, and proved to be very interesting and enlightening. Quite a large attendance was present, and the discussion of various heat treating problems and Mr. Johnson's paper contributed to make it a very profitable evening.

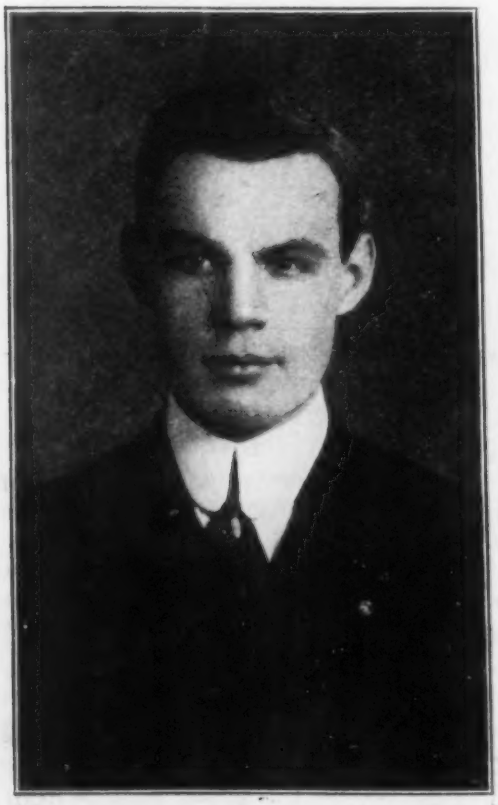
MILWAUKEE CHAPTER

The May meeting of the Milwaukee chapter was held on May 9, and was addressed by Prof. H. F. Moore, of the University of Illinois, on the "Fatigue of Metals". Over 100 were in attendance. The meeting was held jointly with the Milwaukee section of the American Chemical Society. The paper by Prof. Moore was illustrated by moving pictures, and was extremely interesting.

The second meeting for May was held on the 25th when Lt. Col. A. E. White, national president, paid his official visit to the chapter,

RALPH C. SCHWARZ
Re-elected Secretary-Treasurer of Rochester Chapter

C. B. SWANDER
Re-elected Secretary-Treasurer of St. Louis Chapter



D. W. McDOWELL
Re-elected Secretary-Treasurer of Pittsburgh Chapter

ARTHUR COLLINS
Re-elected Secretary-Treasurer of Philadelphia Chapter

and gave a very interesting paper. This meeting was also a business meeting, for the annual election of officers. E. Williams, chairman of the nominating committee, submitted a report of that committee.

PHILADELPHIA CHAPTER

The Philadelphia chapter had a very interesting meeting on April 29 in the auditorium of the Engineers' Club, when over 100 attended to hear Norman Einwechter of Philadelphia present a paper on the subject of "Normalizing Tool Steel and Preparing Same for the Steel Treater". The discussion was very lively and instructive and was participated in by Mr. Nelson, of Henry Disston Sons Co., who has recently arrived in this country, having been associated with the steel interests in Sheffield for a number of years. Mr. Brooks, of the Bethlehem Shipbuilding Corp., and Mr. Dawson, of Philadelphia Navy Yard, presented short talks on "Fundamentals of Heat Treating".

Interest is reaching a very high stage of development with reference to the institution of classes of metallurgy, metallography and heat treating in the Philadelphia schools having evening classes, and the idea at the present time is to have two classes each week for 30 weeks, each class to consist of two hours per night, or a total of 120 hours, including practical work and demonstration. The charge for this course will be approximately $30.00 and will be most complete and ably taught.

ST. LOUIS CHAPTER

The St. Louis chapter held its annual meeting on May 12 at the Planters Hotel with over 75 in attendance to hear Prof. H. F. Moore talk on the "Fatigue of Metals". The chapter enjoyed Prof. Moore's paper very much.

The election of officers resulted in the selection of the following men: Chairman, J. N. Maher, superintendent of the St. Louis Frog & Switch Co.; vice chairman, Chas. G. Kruckemeyer, St. Louis Screw Co.; secretary-treasurer, C. B. Swander, metallurgist, of Wagner Electric Mfg. Co.

BUFFALO CHAPTER

The April meeting of the Buffalo chapter was held on April 25, at which time the following officers were elected for the coming year: Chairman, W. H. Blocksidge, J. H. Williams Co.; vice chairman, W. H. Reiger, Sizer Forge Co.; secretary-treasurer, Hans Buerk, Buerk Tool Works. Two members of executive committee: John Miller, Pierce Arrow Motor Car Co.; C. E. McQuigg, Electro-Metallurgical Corp.

TRI-CITY CHAPTER

On May 11, the Tri-City chapter held its meeting at the Davenport Chamber of Commerce, and was addressed by Prof. H. F. Moore, of the University of Illinois, on the subject of "Fatigue of Metals". About 80 were in attendance and enjoyed a very excellent meeting.

The new officers for the Tri-City chapter as as follows: Chairman, Mr. A. H. Putnam, P. O. Box 653, Davenport, Iowa; vice chairman, J. F. Lardner, 723 20th St., Rock Island, Ill.; secretary-treasurer, C H. Lage, Linograph Co., Davenport, Iowa.

Executive committee: The three officers of the chapter and L. S. Rasmussen, Linograph Co., Davenport, Iowa; Harold Brown, Reynolds Engineering Co., Moline, Ill.

WASHINGTON CHAPTER

The May meeting of the Washington chapter was held in the ballroom of the Harrington Hotel, E Street, on Thursday, May 19. The subject

for discussion was the heat treatment of heavy forgings, and papers were delivered by Lawford H. Fry, superintendent of product, Standard Steel Works, Burnham, Pa., on "Theory and Practice in Quenching Large Locomotive Forgings", and also by Paul E. McKinney, metallurgist, United States Naval Gun Factory, Washington, D. C., on "Heat Treatment of Ordnance Forgings". Since both speakers are actively engaged in the heat treatment of steel, the papers dealt with practical metallurgical problems involved in the treatment of such work, more especially the influence of mass and temperature on the quality of the finished product. The meeting was very well attended and proved to be one of the best held by the chapter.

LEHIGH VALLEY CHAPTER

The Lehigh Valley chapter had a very successful meeting at the Public Library in Easton, when 150 were in attendance. The speaker of the evening was W. R. Shimer, sales metallurgist, Bethlehem Steel Co., Bethlehem, Pa., whose subject was "Manufacture of Steel".

The following officers for the year 1921-1922 were elected: Chairman; J. E. Halbing, Ingersoll-Rand Co.; secretary-treasurer, A. P. Spooner, Bethlehem Steel Co.

Executive Committee: H. Brainard, Ingersoll-Rand Co., Phillipsburgh, N. J.; R. Christ, Bethlehem Steel Co., Bethlehem, Pa.; W. R. Shimer, Bethlehem Steel Co.; G C. Lilly, 606 North Market St., Bethlehem, Pa.; F. Martin, Ingersoll-Rand Co., Phillipsburgh, N. J.; A. Hummel, William Wharton Jr. Co., Easton, Pa.; F. Ebner, 1922 Freemans Ave., Easton, Pa.; W. Laury, Bethlehem Steel Co., Bethlehem, Pa.; L. Larkin, M. E. Lehigh University, Bethlehem, Pa.

NEW YORK CHAPTER

The New York chapter held its May meeting at the Machinery Club, Hudson Terminal Building, 50 Church St., on Monday evening, May 18. S. P. Rockwell, metallurgist of the Whitney Mfg. Co., Hartford, Conn., presented a lecture on "Hardness Testing", which was illustrated by stereoptican views. Mr. Rockwell discussed and compared various methods of determining hardness of metals, and in particular the Rockwell hardness tester, invented by the speaker. About 75 members were present, bringing with them specimens of materials for testing. A very lively and interesting discussion and demonstration followed the paper.

The new officers of the New York chapter are as follows: Chairman, George L. Norris, Vanadium Corp. of Amer., New York City; chairman of entertainment committee, A. E. Barker, Firth-Sterling Steel Co.; secretary-treasurer, T. N. Holden Jr., chemist, E. W. Bliss Co., Brooklyn.

CINCINNATI CHAPTER

The regular meeting of the Cincinnati chapter was held on Friday, May 20, at the Ohio Mechanic Institute, Cincinnati. The paper of the evening was presented by C. P. Richter, of the Central Steel Co., Massillon, Ohio, who selected for his subject "Alloy Steel and Common Sense". The speaker handled the subject in a very interesting and entertaining manner, and the 60 members in attendance had a very enjoyable evening.

The election of officers was held at this meeting and resulted in the following selections: Chairman, R. M. Taylor, American Tool Works Co.; vice chairman, A. L. Meyers, R. K. Leblond Machine Tool Co.; secre-

tary-treasurer, Fred L. Martin, National Metal Trades Ass'n., 706 Elm St.

Executive Committee: W. T. Cowell, Lodge & Shipley Machine Tool Co.; J. H. Nead, American Rolling Mill Co., Middletown, O.; W. R. Fleming, Andrews Steel Co., Newport, Ky.; E. S. Sawtell, Tool Steel Gear & Pinion Co.; Geo. Langen Jr., Advance Tool Co.

NORTH WEST CHAPTER

The North West Chapter of the Society held its May meeting on May 10 in the rooms of the Manufacturers Club. Prof. H. F. Moore, was honor guest for the evening and addressed the members on the "Fatigue of Metals", which was illustrated by lantern slides. Prof. Moore is recognized as one of the foremost authorities on this subject and for some time has been in charge of exhaustive research conducted under the auspices and at the expense of the National Research Council, Engineering Foundation of the Carnegie Institute, and the Experimental Station of the University of Illinois.

The following officers were elected for the coming year: Chairman, Prof. Oscar E. Harder, instructor in metallurgy, University of Minnesota; vice chairman, H. K. Briggs, metallurgist, Minneapolis Electric Steel Castings Co.; secretary-treasurer, Alexis Caswell, secretary Manufacturers Club.

INDIANAPOLIS CHAPTER

The Indianapolis chapter held its May meeting on the 2nd which was addressed by William L. Patterson, of Bausch & Lomb Optical Co., on the "Optics of Metallography." The following officers were elected for the coming year: Chairman, Arthur L. Cramp, general foreman, Lafayette Motors, Indianapolis; vice chairman, Paul O. Deeds, vice president, Deeds & Chapin Co., Indianapolis; secretary-treasurer, Paul Smith, chemist, 122 E. Ohio St., Indianapolis.

HARTFORD CHAPTER

The Hartford chapter held its May meeting on the 12th, at the Hartford Y. M. C. A., when papers were presented by E. L. Wilson, president of Connecticut Electric Steel Co., on "The Electric Furnace", and by Marcus E. Gere, on the "Crucible Process in Manufacture of Steel". Both papers were heartily received, and the discussions following, on "Tungsten" and "Shop Problems", were participated in by most of those present. At this meeting the annual election of officers was also held.

SYRACUSE CHAPTER

The monthly meeting of the Syracuse chapter was held on May 20, in the Hiawatha room of the Onondaga Hotel, when Lt. Col. A. E. White, national president was the honor guest. A dinner at the University Club was tendered Lt. Col. White and was attended by about 100.

The chapter entertained as guests, W. H. Eisenman, national secretary; J. E. Halbing, assistant superintendent of heat treating, Ingersoll Rand Co., Phillipsburg, N. J.; C. E. McQuigg, metallurgist of the Electro-Metallurgical Corp., Buffalo; J. J. Morrow, inspection engineer Steel Co. of Canada, Ltd., Hamilton, Ont.; and members of the Constitution and By-Laws Committee who held an important session in Syracuse on that day.

The following officers for the coming year were also elected: Chairman, Howard J. Stagg, assistant general manager, Halcomb Steel Co.;

vice chairman, F. C. Rabb, metallurgist, 324 Borden Ave.; secretary-treasurer, Wm. F. McNally, metallurgist and chemist, Willys Corp., New Process Gear Div.

DETROIT CHAPTER

The annual dinner meeting of the Detroit chapter was held in the Board of Commerce rooms at 6:30 P. M., on May 31, Lt. Col. A. E. White, being the speaker of the evening. He gave a very interesting presentation of his subject.

One of the most important events of the evening was the presentation to Prof. Edward DeMille Campbell, of a certificate of Honorary Membership in the National Society. This certificate was presented by Lt. Col. White. Prof. Campbell accepted it with an expression of deep appreciation of the honor conferred upon him.

At this meeting the election of officers for the coming year was held, with the following results: Chairman, L. A. Danse, metallurgist Cadillac Motor Co., 4432 Vermont Ave.; vice chairman, H. J. Lawson, general heat treating foreman, Cadillac Motor Co., 568 Hague Ave.; secretary-treasurer, J. L. McCloud, Ford Motor Co., 560 Nona Ave., Dearborn, Mich.

Executive Committee—C. G. Heilman, chemist and metallurgist, General Motors Corp., 5831 Cass Ave.; W. J. Learmonth, superintendent, Plant 4, Studebaker Corp., 8340 Dexter Blvd.; W. G. Calkins, metallurgist, Detroit Twist Drill Co., 1608 Pingree Ave.; A. W. Copeland, president, Detroit Gear Machine Co., 670 E. Woodbridge St.; J. M. Watson, metallurgist, Hupp Motor Car Corp.

NEW HAVEN CHAPTER

The annual meeting of the New Haven chapter was held on May 11 at the Winchester Engineering Club House, when "The Story of Steel" was presented by a series of moving pictures, together with a talk by G. A. Richardson, Midvale Steel & Ordnance Co. The election of officers for the coming year was also held at this meeting.

CHICAGO CHAPTER

The annual meeting of the Chicago chapter was held on May 16 at Steven's Restaurant when John W. O'Leary gave a very interesting discussion on "The Relation of the Steel Treaters to the Present Economic Conditions". The following officers were elected for the ensuing year: Chairman, H. F. Wood, metallurgist, Ingalls Shepard Div., Wyman Gordon Co., Harvey, Ill.; vice chairman, P. A. Lovegreen, superintendent forge shop, Standard Forgings Co., Indiana Harbor, Ind.; secretary-treasurer, Harry Blumberg, metallographist, Illinois Steel Co., South Works, Chicago, Ill.

Members of Executive Committee: F. C. Wheeler, mechanical engineer, Miehle Printing Press & Mfg. Co., Chicago, Ill.; H. T. Moore, metallurgist, Tuthill Spring Co., Chicago; B. R. Kane, foreman heat treating department, Goodman Mfg. Co., Chicago, Ill.

CLEVELAND CHAPTER

The Cleveland chapter held its annual meeting on May 27 at the rooms of the Engineering Society at the Statler Hotel. The paper of the evening was presented by Wm. L. Patterson, research engineer of Bausch & Lomb Optical Co., upon the subject of "The Optics of Metallography". Mr. Patterson gave a very interesting and entertaining de-

scription in detail of the proper use of the microscope in metallurgical laboratories.

The election of officers for the ensuing year was also held with the results as follows: Chairman, Charles G. Shontz, metallurgist, Perfection Spring Co.; vice chairman, R. S. Archer, metallurgical department, Aluminum Castings Corp.; secretary-treasurer, Ray T. Bayless, metallurgist, James H. Herron Co. Members of board of directors, J. V. Emmons, metallurgist, Cleveland Twist Drill Co.; Charles Campbell, superintendent, Pioneer Alloy Products Co.; Prof. H. M. Boylston, professor of Metallurgy, Case School of Applied Science; Samuel L. Hoyt, metallurgical engineer, National Lamp Works, Nela Park.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ADAMS, Jos. O. (M-4), 930 Church St., Indianapolis, Ind.
ANDERSON, Richard (M-5), 2822 Colfax Ave. N., Minneapolis, Minn.
APPEL, W. L. (M-4), 1908 N. Jersey St., Indianapolis, Ind.
ATKINS, G. F. (M-4), 109 E. St. Clair St., Indianapolis, Ind.
BACON, Wm. (M-5), Reed-Prentice Co., 667 Cambridge St.,
BARR, Gilbert J. (M-5), Standard Piston Pin Co., Racine, Wisconsin.
BELLOWS, Hubbard F. (M-5), Walden Worcester Inc., Worcester, Mass.
BOTTOME, Tibbitts R. (M-4), 621 E. 24th St., Indianapolis, Ind.
BROCE, W. T. (M-5), Third Ave. & E St., South Charleston, W. Va.
BUNCOCK, James A. (M-5), 150 Lincoln St., Worcester, Mass.
CARDEN, Alfred G. (M-5), 1305 24th St., Milwaukee, Wis.
CLARK, Earle D. (M-5), Crompton & Knowles Loom Wks., Worcester, Mass.
CRANSTON, Joseph P. (M-5), 304 Maple St., Fort Atkinson, Wis.
DANIELS, C. W. (M-6), 5 Montrole Road, Worcester, Mass.
DIETZMAN, H. M. (M-3), 615 Collings Ave., West Collingswood, N. J.
DOWNEY, N. J. (M-5), 32 William St., Wallingford, Conn.
EKLUND, Oscar F. (M-6), Norton Co., Worcester, Mass.
FARMER, De Lotus (M-4), 1223 Villa Ave., Indianapolis, Ind.
GEHLERT, Wm. E. (M-4), 630 Washington St., Gary, Ind.
GEISSINGER, H. G. (A-4), H. L. W. Mfg. Co., 20th & Fort, Detroit, Mich.
GIBBONS, C. J. (M-5), Worcester Pressed Steel Co., Worcester, Mass.
GRAHAM, Alvin K. (M-4), Kirk-Latty Co., 85th St. & Madison Ave., Cleveland, O.
GROESBECK, E. C. (M-4), 1627 19th St. N. W., Washington, D. C.
HAGADONE, E. B. (M-4), 406 Madison St., Gary, Ind.
HANRAHAN, J. T. (M-4), 2302 Pierson Ave., Indianapolis, Ind.
HAWKINS, E. R. (M-4), Y. M. C. A., Gary, Ind.
HJORTH, O. B. (M-5), Parker Pen Co., Janesville, Wis.
HODGE, John E. (M-5), 1921 Irving Ave. S., Minneapolis, Minn.
HODGEON, Henry (M-3), 463 Dale Ave., Muskegon, Mich.
HOLDEN, Geo. H. (M-3), Naval Ordnance Plant, S. Charleston, W. Va.
HOLM, Carl I. (M-4), Y. M. C. A., Gary, Ind.
HOLMES, J. H. Jr. (A-3), 2031 12th St., Boulder, Colo.
IRONS, W. V. (M-4), University of Buffalo, Buffalo, N. Y.
KALLSTEDT, C. H. (A-3), Peoples Gas Lt. & Coke Co., 1229 S. State St., Chicago, Ill.
KEMP, Felix (M 4), Atlas Crucible Steel Co., Dunkirk, N. Y.

KENNEDY, C. J. (M-4), American Bridge Co., Gary, Ind.
KLANCKE, Hermann (M-5), 613 Plantation St., Worcester, Mass.
KLINKICHT, W. R. (M-5), 318 Piedmont Ave., Cincinnati, Ohio.
KORB, L. F. (M-4), 8644 Hamilton Rd., Detroit, Mich.
KURCZYUSKI, L. (M-4), 1588 N. 12th St., St. Louis, Mo.
LANGHAAR, L. (M-4), Langhaar Ball Bearing Co., Aurora, Ind.
LATHAM, W. E. (M-3), E. Howard Watch Wks., Waltham, Mass.
LEARNED, E. D. (M-5), 11 Foster St., Worcester, Mass.
LEECH, John (M-4), International Silver Co., Bridgeport, Conn.
LEGGE, Elmer E. (M-5), American Steel & Wire Co., Worcester, Mass.
LISK, Alec. M. (M-4), 1959 Scotten, Detroit, Mich.
LONG, C. W. (M-3), 2300 E. Tioga St., Philadelphia, Pa.
LORD, James O. (M-4), 360 Adams St., Gary, Ind.
LUCAS, R. B. (M-4), Illinois Steel Co., Gary Wks., Gary, Ind.
MEYER, E. C. (M-5), Arcade Malleable Iron Co., Worcester, Mass.
MILLER, C. W. (Sb-5), Steel Products Co., 2196 Clarkwood Rd., Cleveland, Ohio.
MONAHAN, J. B. (M-4), Illinois Steel Co., Gary Wks., Gary, Ind.
MORAN, John H. (Sb-5), Ellis Jackson & Co., 18 N. Front St., Philadelphia, Pa.
MORI, Fukutaro (Sb-4), Maeda, Haradamura Mokogun, Hyogoken, Japan.
MORRIS, T. B. (A-4), 2101 Western Ave., Cincinnati, Ohio.
MUNGAN, J. J. (A-4), 617 Ford Building, Detroit, Mich.
McCOMB, Herbert (M-5), 573 Tyler St., Gary Ind.
McCORMICK, Geo. C. (M-5), Crompton & Knowles Loom Wks., Worcester, Mass.
NASH, Francis (M-3), 1521 Green St, Philadelphia, Pa.
NELSON, Geo. W. (M-5), 37 Sterling St., Worcester, Mass.
OBERTING, Chas. (M-4), 1134 Kelly St., Indianapolis, Ind.
OLSEN, Carl L. (M-4), 1310 Beville Ave., Indianapolis, Ind.
PRIESTER, Geo. C. (M-5), University of Minn., College of Engr., Minneapolis, Minn.
PUSITZ, Lubomis (M-4), 1325 Theodore, Detroit, Mich.
RACHEFF, Ivan (M-4), 438 Mass. St., Gary, Ind.
RAMSTROM, D. L. (M-6), Norton Co., Worcester, Mass.
ROBERTS, T. (M-5), C. H. Wheeler Mfg. Co., 18th & Sedgeley Ave., Philadelphia, Pa.
ROBINSON, S. R. (M-4), Sandusky Foundry & Mch. Co., Sandusky, Ohio.
ROTH, Max H. (M-5), Falls Motor Corp., Sheboygan Falls, Wis.
SMITH, G. W. (M-5), Nash Motors Co., Milwaukee, Wis.
SPALDING, Edwin A. (M-5), 29 Oberlin St., Worcester, Mass.
SPENCE, John C. (M-5), 16 Davidson Rd., Worcester, Mass.
SPENCER, W. E. (M-4), Plant No. 3, Studebaker Corp., Detroit, Mich.
SUDDARD, Thos. (M-5), Hamilton Mfg. Co., Two Rivers, Wis.
TERWILLIGER, S. (M-4), 150 Morley, Dearborn, Mich.
TREVELEYAN, H. A. (M-5), 5038 Crane, Detroit, Mich.
WASHBURN, J. M. (M-4), Merrow Machine Co., 28 Laurel St., Hartford, Conn.
WEAVER, Wm. L. (A-5), 315 Partridge St., Albany, N. Y.
WELLS, Chas. A. (M-5), Osgood Bradley Car Co., Worcester, Mass.
WHITE, S. F. (M-6), 18 Euclid Ave., Ludlow, Ky.
WILLETT, John A. (M-4), 1776 Lafayette Blvd., Detroit, Mich.
WILLEY, O. C. (M-4), 4813 Whetzel Ave., Madisonville, Ohio.
WOOD, Jos. E. (M-4), 2186 Madison Ave., Indianapolis, Ind.
WOOD, Wm. P. (M-6), 1348 Wilmot St., Ann Arbor, Mich.
WOODWARD, A. F. (M-4), 621 G. Street, S. W., Washington, D. C.

CHANGES OF ADDRESS

AMMON, Mark A.—from Willys Overland Co., Toledo, Ohio, to Briscoe Motor Co., Flint, Mich.

ANDERSON, Rich.—from 319 Church St., Brooklyn, N. Y. to 319 Church Ave., Brooklyn, N. Y.

BARACH, S. (M-3), from 439 T. St. N. W. Tuxedo Apt. 308, Washington, D. C. to 1439 T. St. N. W. Tuxedo Apt. 308, Washington, D. C.

BARTLETT, J. W.—from Chas. Tractor Corp., Ltd., 28 Atlantic Ave., Toronto, Ont., Can., to Dunn Edge Tool Co., Oakland, Maine.

BEELER, C. F.—from International Harvester Co., Akron, Ohio, to 10117 Adelaide Ave., Cleveland, Ohio.

BERGGREEN, P. H. (M-5), from Room 281, Bureau of Mines, Pittsburgh, Pa. to Foreign Sales Mgr., Reck Heating Co., Ltd., 15 Esromgade, Copenhagen.

BIHLMAN, V. W. (M-3), from 36 Maple St., Springfield, Mass. to 32 Temple St., Springfield, Mass.

BLUMBERG, Harry—from 1424 W. 14th St., Chicago, Ill. to Illinois Steel Company, South Works, Chicago, Ill.

CHABOT, J. M. F.—from 40 Orchard St., Bristol, Conn. to 30 Orchard St., Bristol.

CHAPMAN, V. J. (M-2), from 141 Fairview Ave., Schenectady, N. Y. to 28 Baker Ave., Schenectady, N. Y.

CULP, John F.—from 271 Horton St. to 268 Horton St., Wilkes Barre, Pa.

DALLMAN, O. H.—from Vanadium Alloys Steel Co., 566 W. Randolph St. to 1528 E. 76th St., Chicago, Ill.

DESARIO, John—from 476 Pawling Ave., Troy, N. Y. to Joliette Castings & Forgings Ltd., Joliette, Quebec, Can.

DIEDERICHE, Wm. J.—from Timken Roller Bearing Co., Columbus, O. to 19 Howard St., Waterbury, Conn.

DRAKE, H. P.—from 2072 E. 79th St. to 2066 E. 79th St., Cleveland, Ohio.

DRAY, W. R.—from International Harvester Co., 113 Center St., Akron, O. to University Club, Chicago, Ill.

DULL, C. E. (M-1), from Buchanan, Mich. to 2056 E. 4th St., Room 501, Cleveland, O.

EDSON, C. S. (A-12), from 4873 Edmonton, to 2150 Concord Ave., Detroit, Mich.

FAIRFIELD, J. A.—from Modern Equipment Co., P. O. Box 415, Foxboro, Mass. to 8 Norfolk St., Needham, Mass.

FORRESTER, W. R.—from Milton Mfg. Co., Milton, Pa. to West Main & Center Sts., Grove City, Pa.

FORSBERG, Uno—from The Hess Bright Mfg. Co., Philadelphia, Pa. to care A. B. Sveniska, Kullagerfabriken, Gothenburg, Sweden.

GAMBLE, W. J.—from Vulcan Steam Forging Co., 247 Rano St., Buffalo, N. Y. to Vulcan Steam Forging Co., 221-253 Rano St., Buffalo, N. Y.

GENSTEIN, E. S. (M-9), from 732 Northampton St., Easton, Pa. to 202 Colonial Bldg., Allentown, Pa.

GORHAM, Wm. R.—from No. 81 Bluff, Yokohama, Japan, to No. 53 Aza Kominato, Kitagate Machi, Juniten, Yokohama, Japan.

HALL, H. G.—from 7300 Oglesby Ave., to 7119 Constance Ave., Windsor Sta., Chicago, Ill.

HAMILTON, D.—from 1239 Kingsley St. to 1124 Chelsea Ave., Lansing, Mich.

HOYT, D. G. (M-11), from 719 Ackerman Ave., Syracuse, N. Y. to Savonia, N.

HUERING, H. (M-12), from 100 First Ave., to 1004 First Ave., Charleston, W. Va.

HUMPHREYSVILLE, L.—from 480 E. 112th St. to 11006 Cedar Ave., Cleveland, O.

JANITZKY, E. J.—from Illinois Steel Co., S. Chicago, Ill. to Illinois Steel Co., South Works, Chicago, Ill.

KIEFER, H. G.—from 1457 Field Ave., to 2911 Iroquois, Detroit, Mich.

LAUPEE, A. A.—from 1518 Gratiot Ave., to 1500 Gratiot Ave., Detroit, Mich.

LEVY, Wm. J. (M-9), from 1126 W. Washbourne Ave., to 5939 S. Elizabeth St., Chicago, Ill.

LUTTENAUER, C. (M-12), from 78 Syracuse St., Baldwinsville, N. Y. to 713 Spaulding St., Elmira, N. Y.

MCCONNELL, J.—from 4752 Ellis Ave., to 2605 E. 73rd St., Windsor Park Sta.,

McDERMOTT, C. C.—from Brown Instrument Co., 111 W. Washington St. to Brown Instrument Co., Conway Bldg., Chicago, Ill.

MCPHERSON, V. J.—from 111 Broad St. to 24 Summer St., Claremont, N. H.

MEEHAN, W.—from U. S. Armory, 36 Maple St., to 32 Temple St., Springfield, Mass.

MITCHELL, F.—from 410 E. 9th St. to 1710 E. Jackson St., Muncie, Ind. Chicago, Ill.

NELSON, John—from 958 College Ave., Beloit, Wis. to Royal Oak, Mich.

NISBEL, Geo. B.—from Erie Smelting & Iron Co. to 643 W. 8th St., Erie, Pa.

PATTERSON, C. T.—from 244 Buckingham Ave., Syracuse, N. Y. to 112 Summit Ave., Solvay, N. Y.

PETERSON, Carl—from 62 Weybosset St., Providence, R. I. to Providence Gas 62 Weybosset St., Providence, R. I.

PHILPOTT, A. D.—from 19 Chalfern Apts., Mansfield, Ohio, to R. F. D. Ventura, Cal.

PUTNAM, A. H.—from Rock Island Arsenal, Rock Island, Ill. to P. O. Box 653, Davenport, Iowa.

ROBINSON, J. W.—from 1305 Seventh St., Port Huron, Mich. to C. H. Wills & Co., Marysville, Mich.

ROSEN, Joe—from Rock Island, Ill. to Linograph Co., Davenport, Iowa.

SCHWAN, Christian—876 to 28th St., Milwaukee, Wis.

SHIPMAN, G. F.—from Washington, N. J. to 404 Thomas St. Phillipsburg, N. J.

SICARD, A. J.—from Ingersoll-Rand Co., Athens, Pa. to 149 Passaic St., Hack-

SMITH, W. R.—from 306 W. Pike St., Cannonsburg, Pa. to 652 Dewey Ave., Bridgeville, Pa.

STORY, J. M.—from 1525 Guardian Bldg., to Bethlehem Steel Co., 1525 Guardian Bldg., Cleveland, Ohio.

SULLIVAN, L. D.—from 1558 Penobscot Bldg. to 4843 Bellevue Ave., Chicago.

SWAN, Christian—from 648 26th St., Milwaukee, Wis.
ensack, N. J.

THEIS, John—from Vanadium Alloys Steel Co., 5933 Haverford Ave., to Vanadium Alloys Steel Co., 601 Franklin Trust Bldg., Philadelphia.

TISDALE, N. F. (M-3), from 11 St. James Ave., to 47 Johnson St., Springfield, Mass.

WALTHER, F. F. (A-1), from 1012 Citizens Bldg. to 414 Union Bldg., Cleveland, O.

WELLS, Glenn H.—from Amer. Locomotive Co., Schenectady, N. Y. to 1141 E. 144th St., Cleveland, Ohio.

WHITE, C. V.—from 225 N. Court St., to 1239 Fairview Ave., Rockford, Ill.

WILLIAMS, W. H. (A-1), from 144 Westminster St., to 144 Wilbraham Rd., Springfield.
WILSON, G. F.—from Ludlum Steel Co., 816 Mercantile Library Bldg., Cincinnati to Ludlum Steel Co., Real Estate Trust Bldg., Philadelphia, Pa.
WOODS, E. L. (M-12), from 102 Thompson St. to Springfield Gas Light Co., 35 State St., Springfield, Mass.
YEOMANS, L. I.—from 72 W. Adams St. to Room 1308 Monadnock Bldg., 53 W. Jackson Blvd., Chicago, Ill.

MAIL RETURNED

ARBUTT, George C., 409 Wilsons Rd., Christ Church, New Zealand.
BARDWELL, J. F. Mgr. Edgar T. Ward's Sons, 304 Hudson St., New York.
BLOCKSIDE, W. H., 1018 Lafayette Ave., Buffalo, N. Y.
CANDLIN, Walter, care Mrs. V. Graham, 157 Augustine St., Rochester, N. Y.
CLELAND, Theo. G., Standard Fuel Appliance Co., 1646 Woodward Ave., Detroit.
EVANS, H. J., New Kensington, Pa.
HANSON, H. E., 3614 64th Ave., West Allis, Wis.
HOENSCHEID, Ralph, Hoenscheid Steel Treating Co., 845 Fort St. W. Detroit.
HORN, Harry T., 103 W. Alexandrine Ave., Detroit, Mich.
KIRMHAM, W. J., 715 School St., Jamesville, Wis.
WINGERT, G. H., Adams Axle Co., Findlay, Ohio.

Commercial Items of Interest

Catalog No. 121 issued by the Simonds Mfg. Co., Lockport, N. Y., is a very elaborate, 94-page flexible leather bound booklet 4½ x 7 inches, containing a wealth of useful information and reference tables, completely indexed. The forepart of the book contains information regarding the company's products of bars, billets or slabs, sheets, strips or bands, crucible and electric tool and alloy steels. A number of plant views of the company's mills are shown. Following this are given complete specifications for each grade, together with heat treating data. A full-page chart shows the various heat colors with their approximate temperatures. The last 27 pages contain standard tables of weight per lineal foot of various sizes and sections of steel.

Mathew C. Brush, formerly president of the Boston Elevated Railway and the American International Shipbuilding Corp., and at present vice president of the American International Corp., 120 Broadway, New York, and H. M. Baruch, of H. Hentz & Co., bankers, 22 William street, New York, recently were elected directors of the Poldi Steel Corp. of America, 115 Broadway, New York.

Features of the May issue of The Melting Pot, published by the Chicago Flexible Shaft Co., Chicago, were: "A Shop Talk on High Speed Steel", "Critical Points of Steel", and "Hardening Thread Gages".

"Oil Burners and Combination Oil and Gas Burners for Industrial Furnace Application" is the title of a bulletin distributed by the George J.

(*Continued on page* 44)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelop containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS OPEN

Assistant superintendent in forge laboratory in large University in Middle West. Applicant must be familiar with modern methods of heat treatment of steel and with forge shop management. Age not over 28 or 30. College training desirable but not required. Position open Sept. 1, 1921. Good opportunity for young man wishing to enter the profession of teaching. Location Illinois. Address PO-11.

Consulting metallurgical and supply house located in Eastern Pennsylvania will accept representation of leading firms in the manufacture of metallurgical equipment and supplies. Address PO-8

WANTED—In tool and alloy steel research department, 1919-1920 technical graduate, who has specialized in iron and steel metallurgy. Must not be afraid of getting right down to brass tacks in the way of running experimental melting and heat treating furnaces. Duties include wide range of work, and position offers unusual opportunity for future advancement. Address P. O.-7

POSITIONS WANTED

ASSISTANT OR FOREMAN—6 years experience journeyman patternmaker, 3 years pattern shop foreman, experienced in large and small machine and steel mill work. Address 6-2.

METALLURGIST OR HEAT TREATING FOREMAN—With opportunity to become acquainted with every phase of work carried out in department. Technical graduate in metallurgy of leading University in East. 12 years experience as metallurgical chemist, physical testing and research work. 6 years as chief chemist. 36 years old. Married. Salary $250.00 per month. Address 6-1.

CHEMIST-METALLURGIST—Southern location preferred. Purdue graduate. 8 years experience as chief chemist and metallurgist. Very best of references. Salary $200.00. Address 6-3.

CHEMIST OR METALLURGIST: Four years analytical work, blast furnaces, open hearth and by-products plants. Three years as chemist and metallurgist in charge of large crucible and electric furnace, and heat treating. Best of references. No preference as to location. Address 5-1.

CHEMIST, METALLURGIST, or SALES DEPARTMENT: Served two years as chemist on semi-steel, carbon and alloy steels, also high speed steel. One years experience on electric furnace construction. Familiar with heat treatment of high speed steel as well as carbon and alloy steel. Have also worked on cast high speed steel. No preference as to location. Salary $2400. Address 3-4.

WANTED—Position as sales manager, Gentile, of years of experience in tools, tool and alloy steels with unquestionable references in every respect, including many very desirable accounts, thoroughly acquainted with Middle West trade, capable of organizing and handling either main of district office, open to negotiate. Answer 1-33

WANTED—Position as chemist or metallurgist Seven years experience in carbon and alloy steels Thoroughly experienced in laboratory research testing, and shop problems concerning steel. References Answer 1-34

WANTED—Position as chief or assistant metallurgist. Graduate of University of Michigan. Five years' experience with largest motor car manufacturing companies. Salary $3600.00 Answer 1-5

WANTED—Position as metallurgist. College training. Qualified to direct chemical laboratories. Thoroughly experienced in modern physical test methods, pyrometers, foundry and plant control. A-1 references. Michigan territory desired. Answer 1-6.

WANTED—Metallurgical position. College graduate in metallurgy. 26 years old. Has been employed with large steel concern having control of pyrometers. Has also done metallographic work. Answer 1-7

WANTED—Position as metallurgist. Capable of directing heat treating department and chemical laboratory. 8 years' experience in forging and steel stamping field. Answer 1-18

WANTED—Position as metallurgist in New England territory. Married. College graduate. Extensive experience in analysis and testing carbon and alloy steels in automobile and aircraft plants, also industrial research. Salary $60.00 a week. Answer 1-9.

WANTED—Position as foreman of heat treating plant. 37 years old. Married. Valuable experience. Best references. Detroit territory preferred. Answer 1-10

WANTED—Position in vocational shop training or foreman of production department. Graduate of University of Missouri. Extensive experience. A-1 references. Missouri or Illinios locality preferred. Answer 1-11

WANTED—Position as foreman of heat treating department. 5 years' in charge of large automobile company's plant. Best of references. Detroit territory preferred. Answer 1-12

WANTED—Position as metallurgist in Chicago or vicinity. Married. 30 years old. 3 years in Chicago Technical College. 6 years' practical experience. Salary $3000.00. Answer 1-14

POSITION WANTED—As metallurgical engineer in technical or executive capacity. Six years experience in the automotive industry with few well known concerns. Experienced in physical and chemical testing, metallography, design of modern heat treating plants and control. Technical graduate. Married Age 29. Answer 1-15

WANTED—Position as steel salesman. Has large trade in New England states who are users of high speed as well as carbon steels. Is thoroughly experienced man and capable of making demonstrations. Trade consists of some of largest machine companies in East. Can furnish best references as to ability as salesman and as to character. Answer 1-16